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WIRING DIAGRAMS

OF

ELECTRICAL APPARATUS AND INSTALLATIONS

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ELECTRICAL APPARATUS

AND

INSTALLATIONS

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PREFACE

This volume contains a collection of circuit diagrams, representing more or less completely all branches of electrical engineering, with the exception of telephony and telegraphy.

The diagrams have been taken from actual practice. Although some are not new, it has been thought best to include them, either because they illustrate important principles, or because the apparatus shown is still in extensive use. A book of diagrams limited strictly to the latest apparatus would be of little use to the operator or to the repair man.

The diagrams show much more than simple wiring connections. By their use it is possible to lay out a modern switchboard, to connect the apparatus and to understand the principles of operation of the various electrical machines. The reader will obtain information from them in proportion to his training and experience.

Armature winding is omitted, as its proper treatment would require more space than is here available.

The circuit connections are so drawn as to be self-explanatory, thus reducing the necessary text to a minimum.

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SECTION I

D. C. GENERATORS

WIRING DIAGRAMS OF ELECTRICAL APPARATUS AND INSTALLATIONS

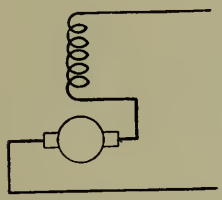


FIG. 1.—Series generator, voltage increases with the load.

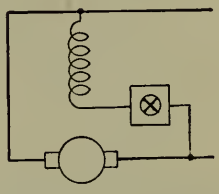


FIG. 2.—Shunt generator, constant voltage dropping off slightly with increase of load.

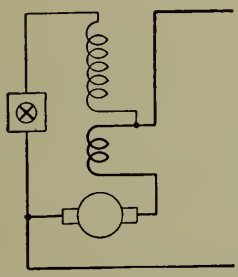


FIG. 3.—Compound generator (short shunt). Constant voltage at the terminals of the generator or at some point in the transmission line.

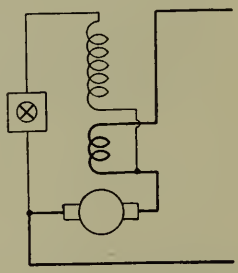


FIG. 4.—Compound generator (long shunt).

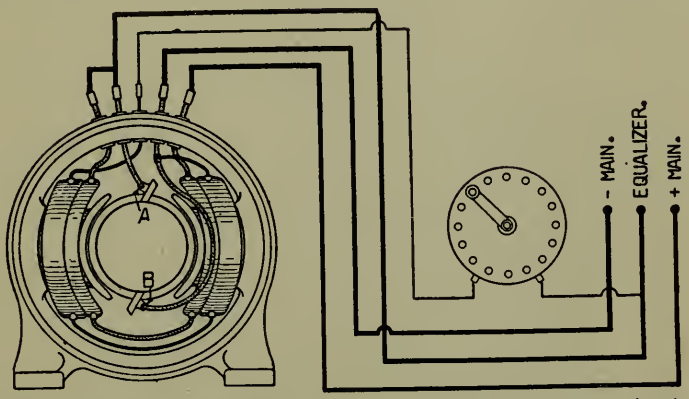


FIG. 5.—Two-pole, compound-wound generator with equalizer for connecting in parallel with similar generators.

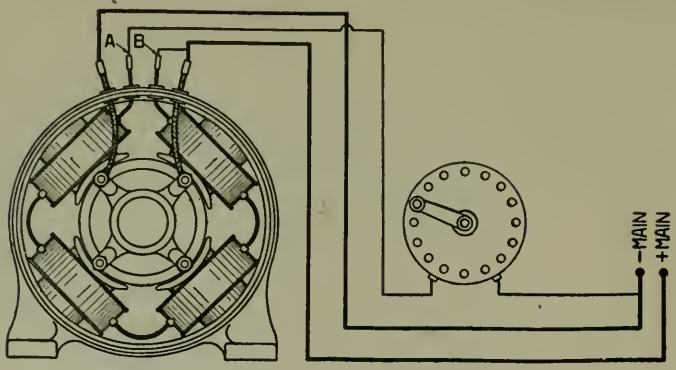


FIG. 6.—Four-pole, shunt-wound generator.

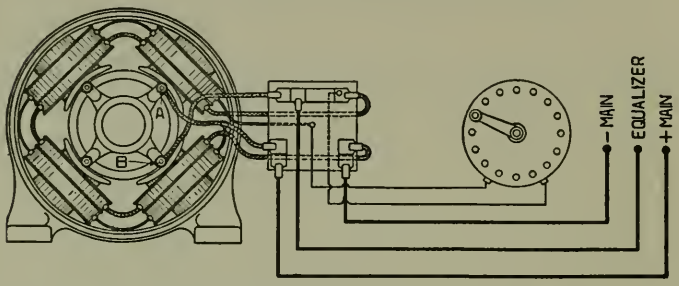


FIG. 7.—Four-pole compound wound generator.

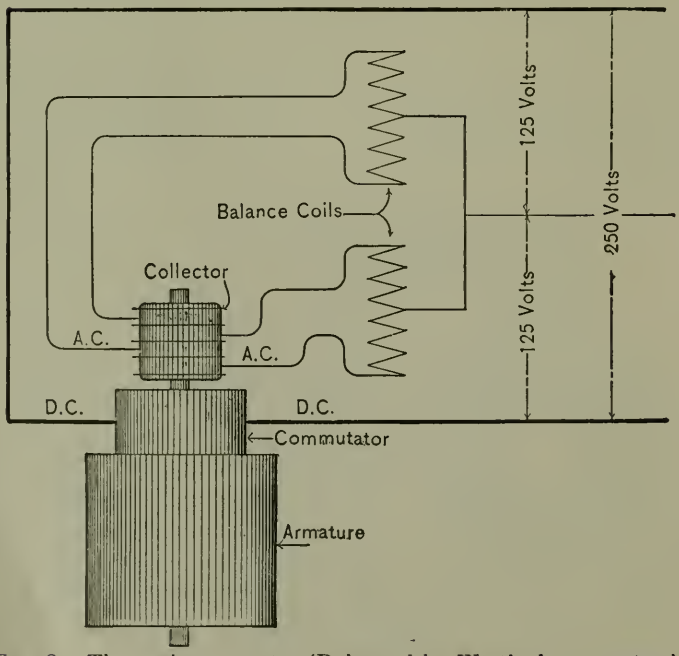


FIG. 8.—Three-wire generator (Dobrowolsky-Westinghouse system).

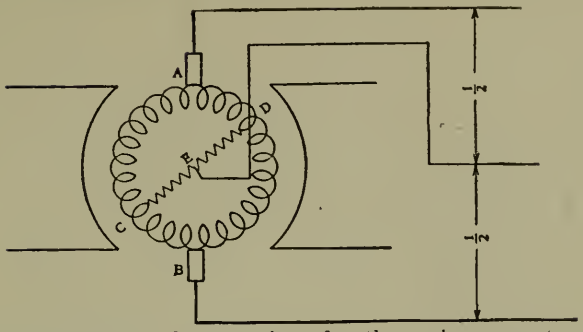


FIG. 9.—Schematic diagram of connections for three-wire generator shown in Fig. 8. The e.m.f. between lines, that is, between E and A, at any instant is the sum of the e.m.f. generated in the armature between A and D and one-half of the e.m.f. impressed across the balancing coils, CD.

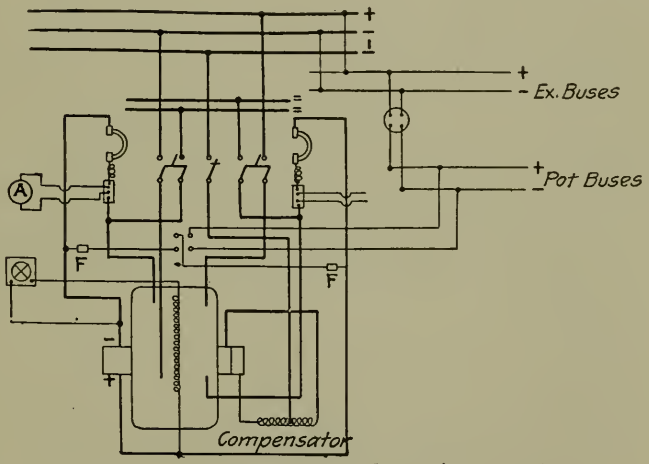


FIG. 10.—Connections of a three-wire generator.

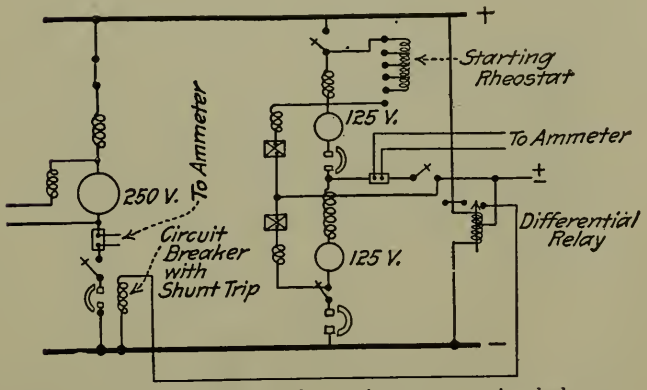


FIG. 11.—Connections of a three-wire system using balancers.

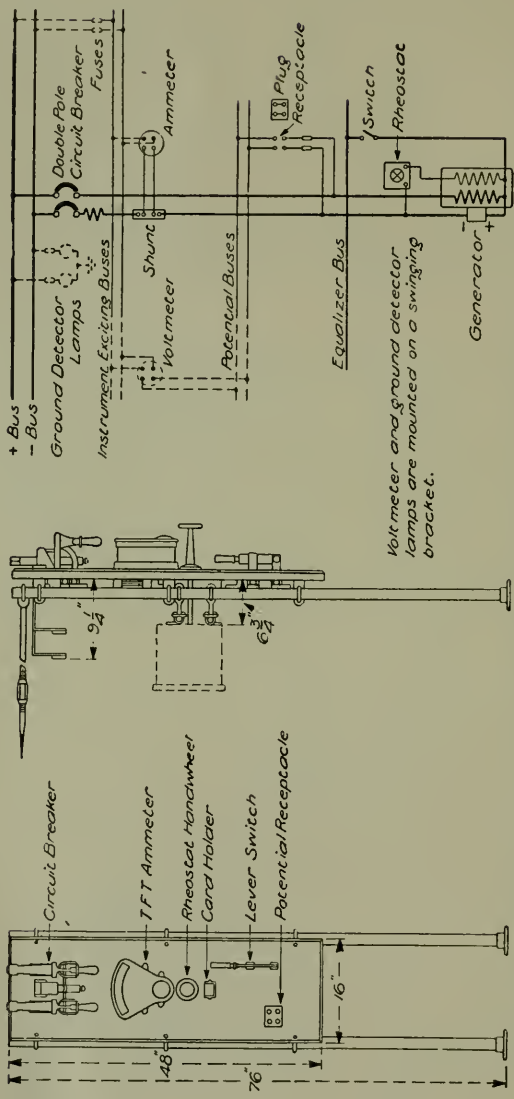


FIG. 12.—Low-voltage, direct-current generator panel with circuit breaker. Rating: 5 to 120 kw., 125 volts, or 10 to 240 kw., 250 volts. Voltmeter to be mounted on swing bracket.

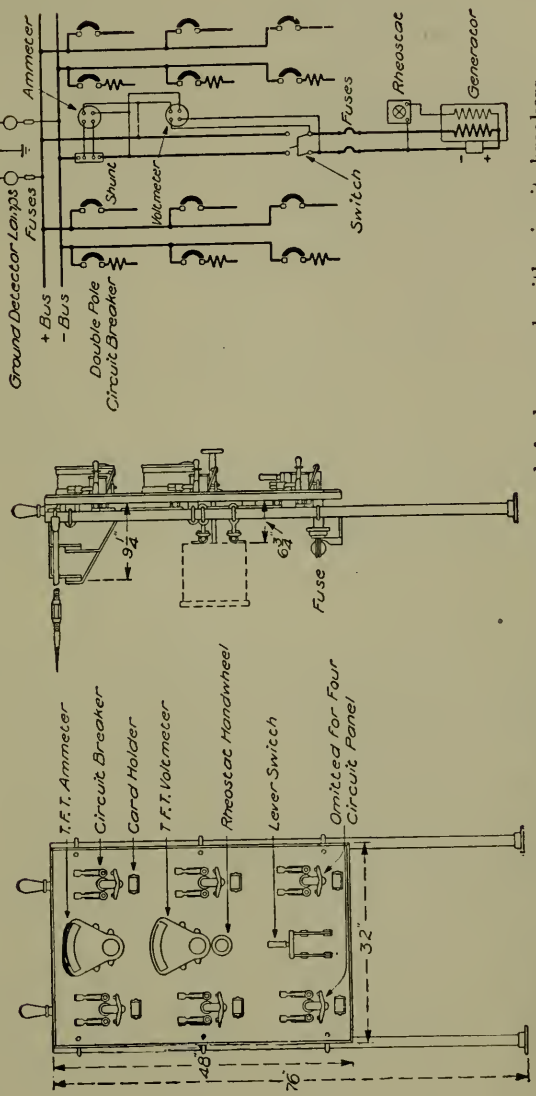


FIG. 13.—Low-voltage, direct-current generator and feeder panel with circuit breakers. Rating: 5 to 120 kw., 125 volts, or 10 to 240 kw., 250 volts.

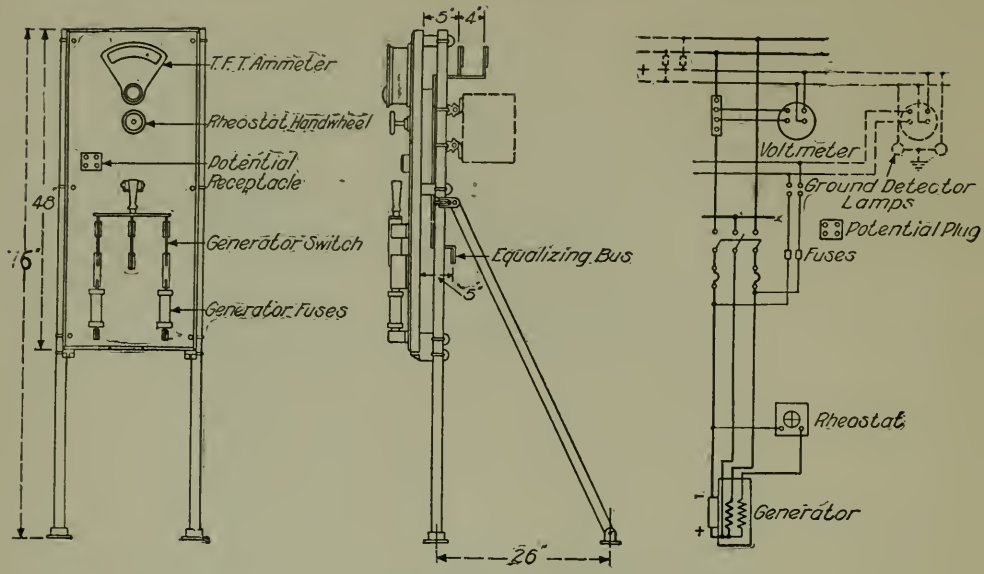


FIG. 14.—Small plant direct-current generator panel. Rating: 5 to 60 kw., 125 volts, or 10 to 120 kw., 250 volts.

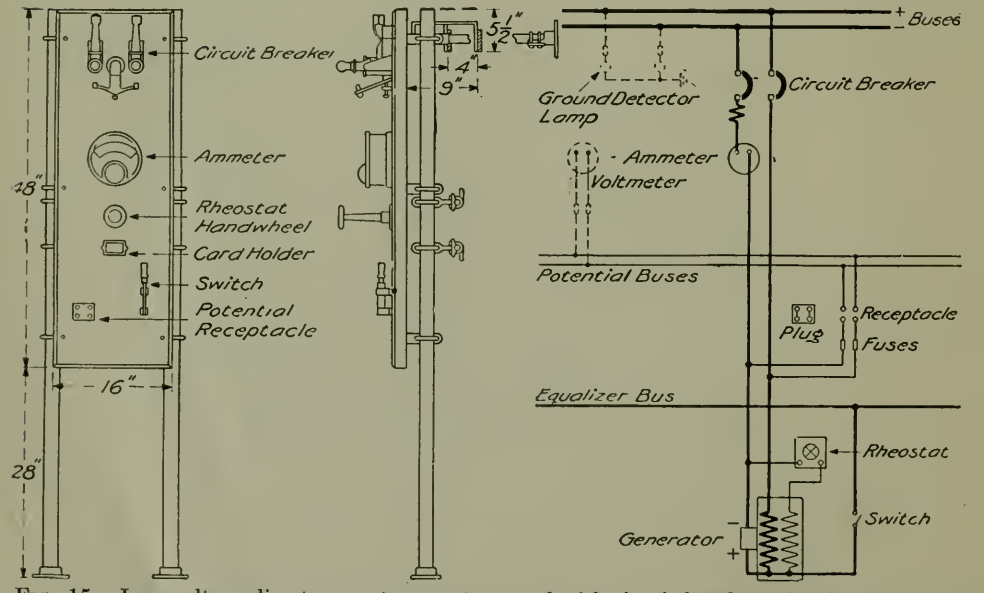


FIG. 15.—Low voltage direct-current generator panel with circuit breaker. Rating: 5 to 120 kw., 125 volts, or 10 to 240 kw., 250 volts. Voltmeter to be mounted on swing bracket.

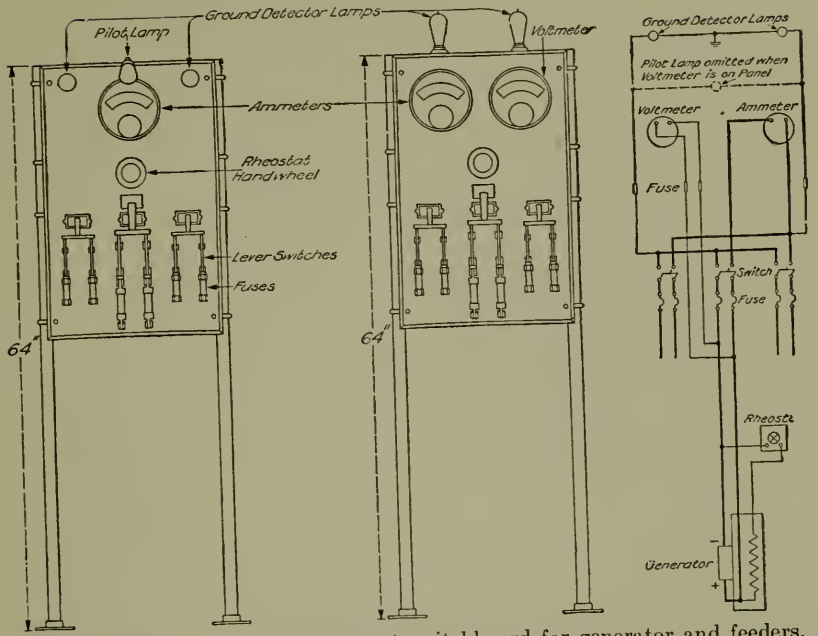


FIG. 16.—Small plant direct-current switchboard for generator and feeders.

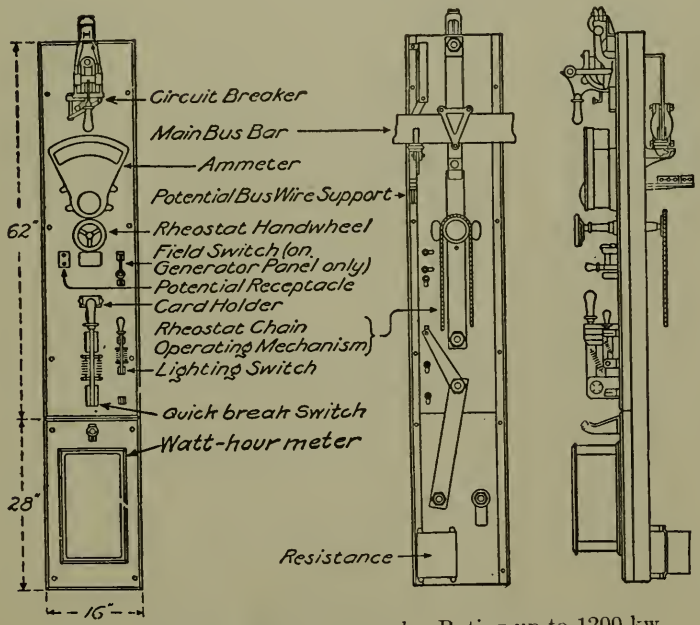


FIG. 17.—Railway generator panel. Rating up to 1200 kw.

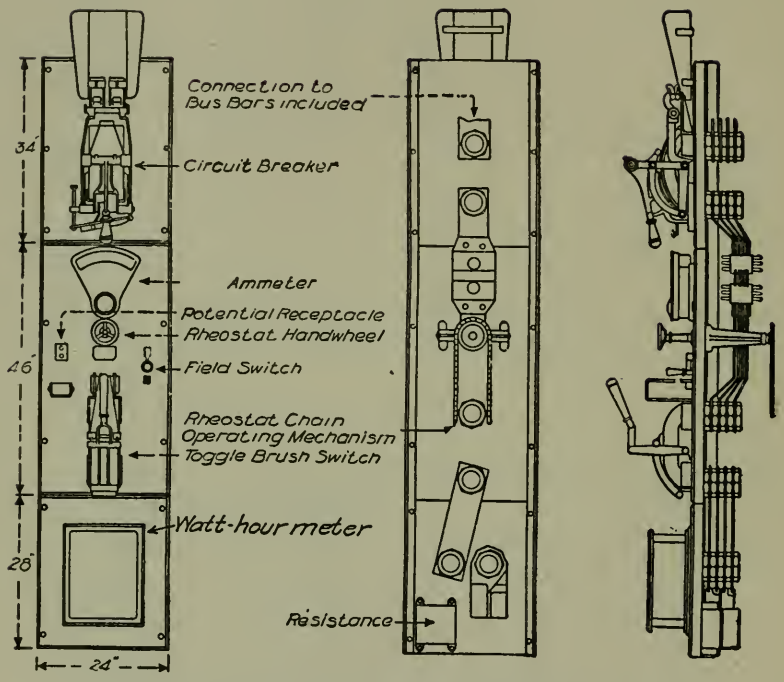


FIG. 18.—Railway generator panel. Rating 1600 kw. and up.

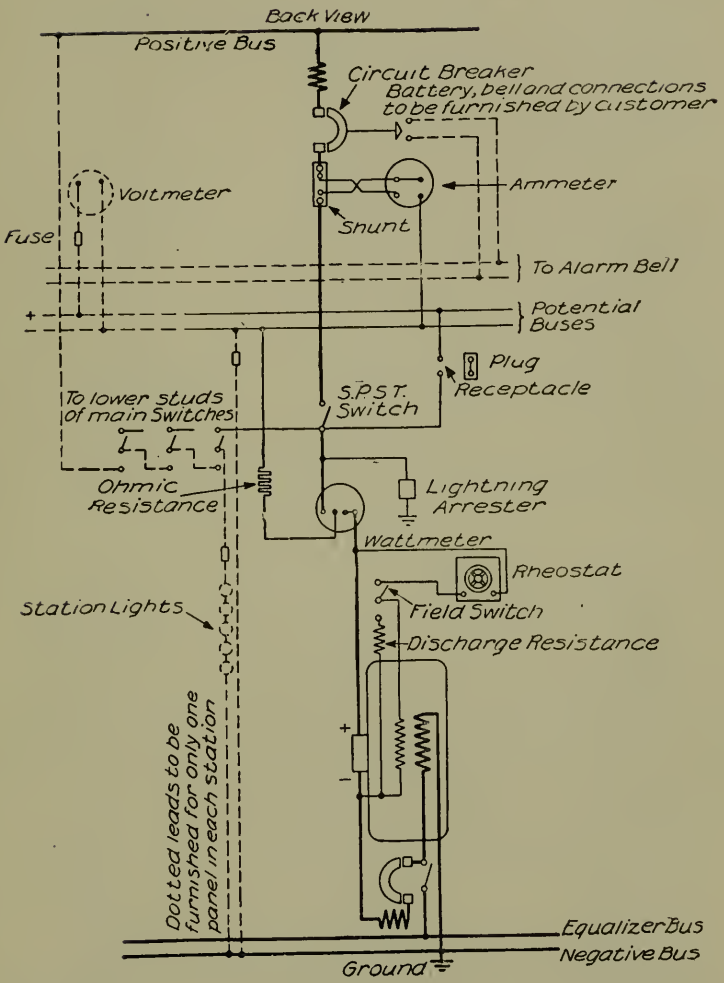


FIG. 19.—Connections for generator panel shown in Figs. 17 and 18.

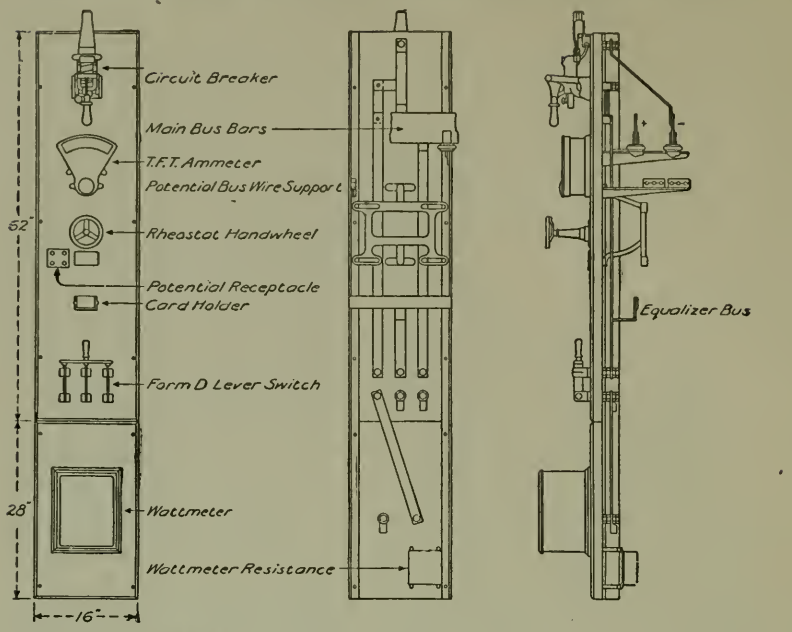


FIG. 20.—Direct-current two-wire generator panel. Rating: 100 to 400 amp., 125 and 250 volts.

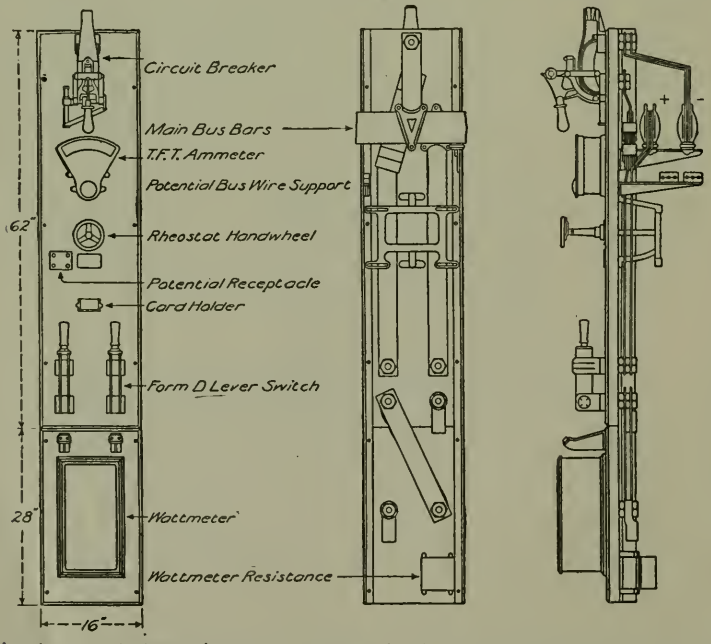


FIG. 21.—Direct-current, two-wire generator panel. Rating: 400 to 1200 amp., 125 and 250 volts.

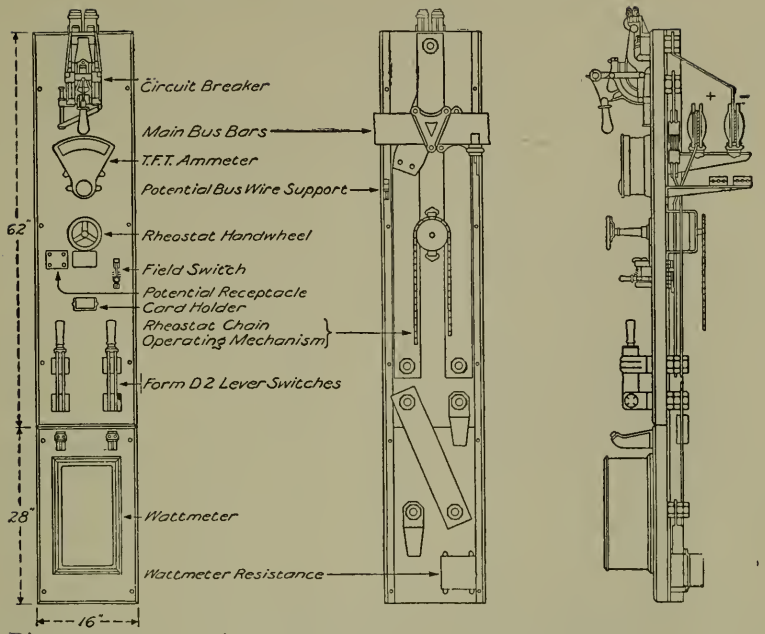


FIG. 22.—Direct-current two-wire generator panel. Rating: 600 to 1600 amp., 125, 250 and 600 volts.

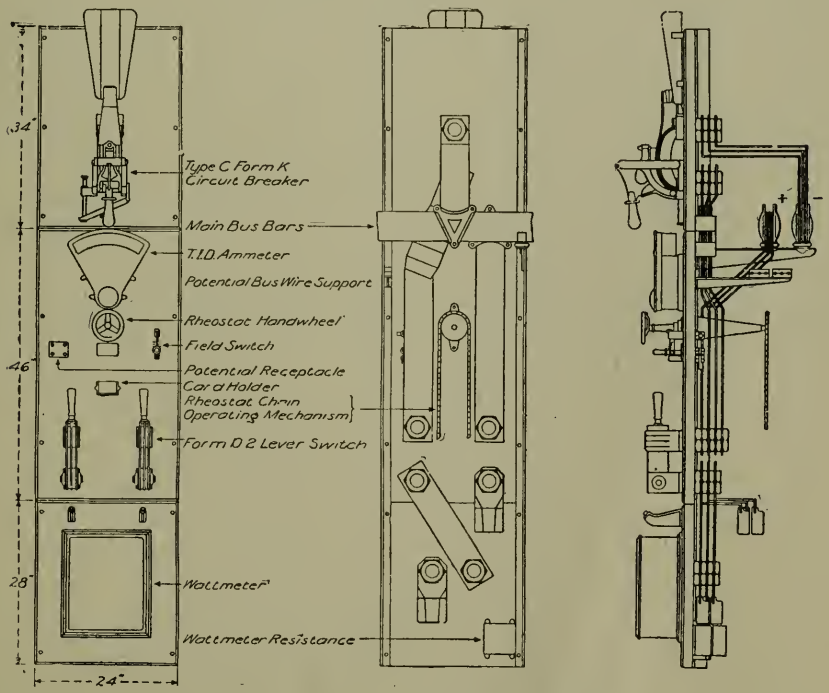


FIG. 23.—Direct-current generator panel. Rating: 400 to 2200 amp., 125 and 250 volts.

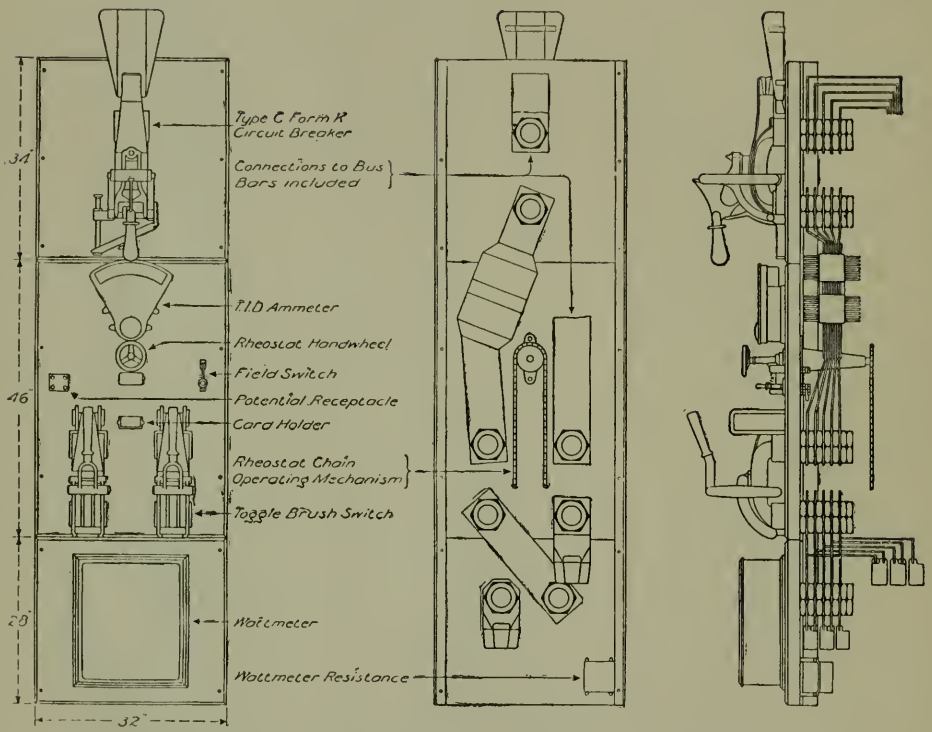


FIG. 24.—Direct-current two-wire generator panel, 2300 to 4000 amp., 250 volts.

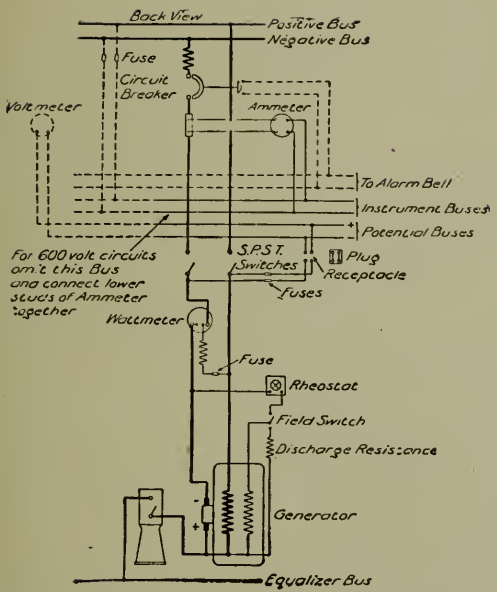


FIG. 25.—Connections for generator panel shown in Figs. 20 to 24.

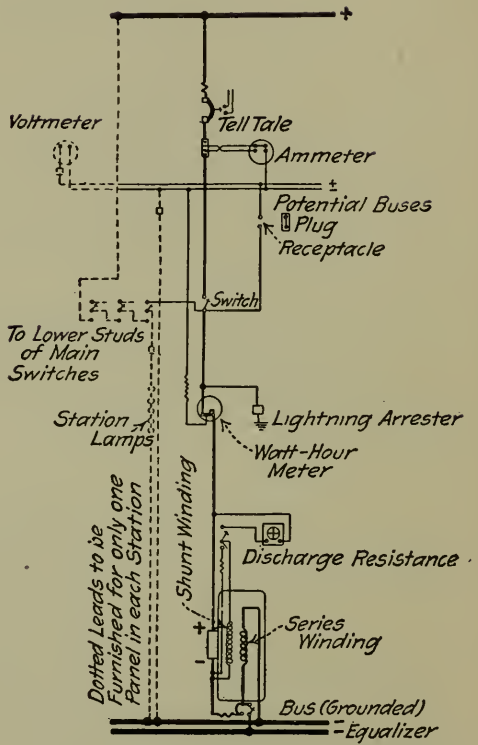


FIG. 26.—Connections for single-pole direct-current generator panel equalized on the negative side.

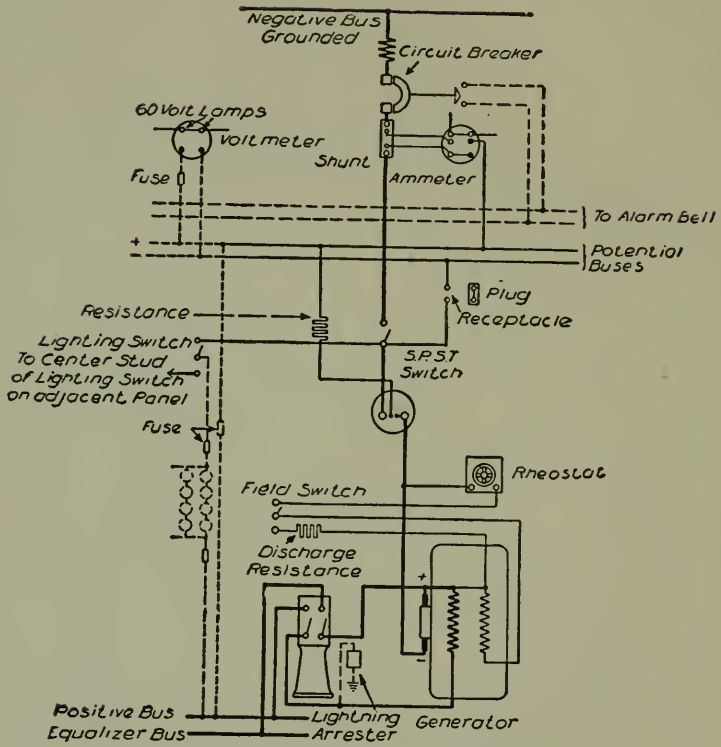


Fig. 27.—Connections for direct-current generator panel, single-pole.

SECTION II

A. C. GENERATORS

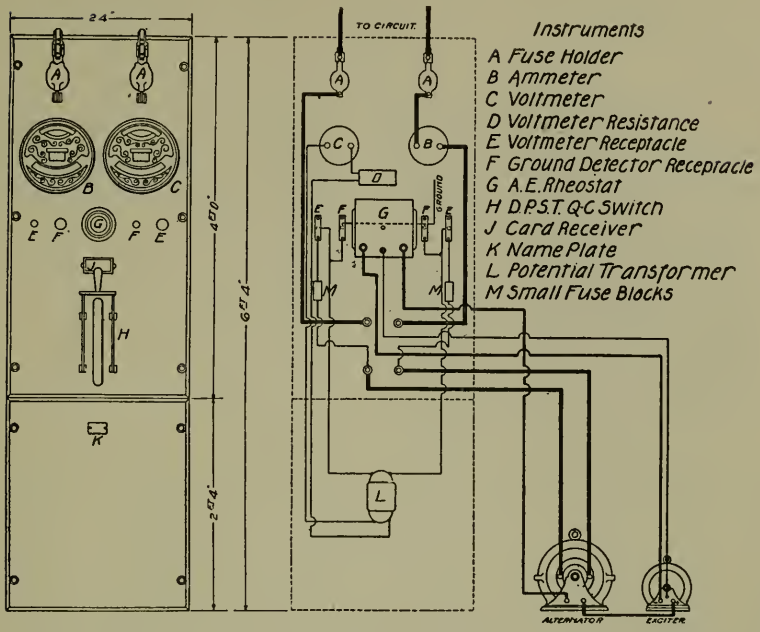


Fig. 28.—Single-phase generator panel. Rating: 7.5 to 150 kw., 1150 volts, or 15 to 300 kw. 2300 volts.

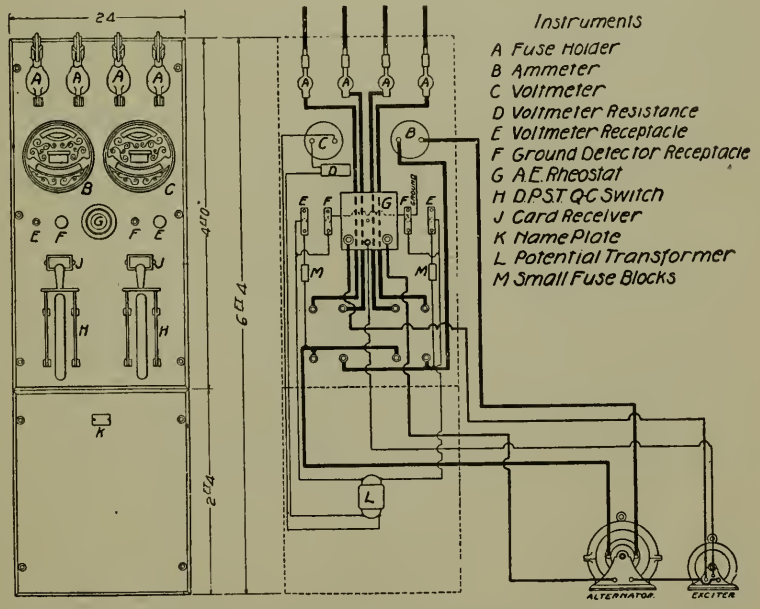


Fig. 29.—Single-phase generator and feeder panel. Rating: 15 to 300 kw., 1150 volts, or 30 to 600 kw., 2300 volts.

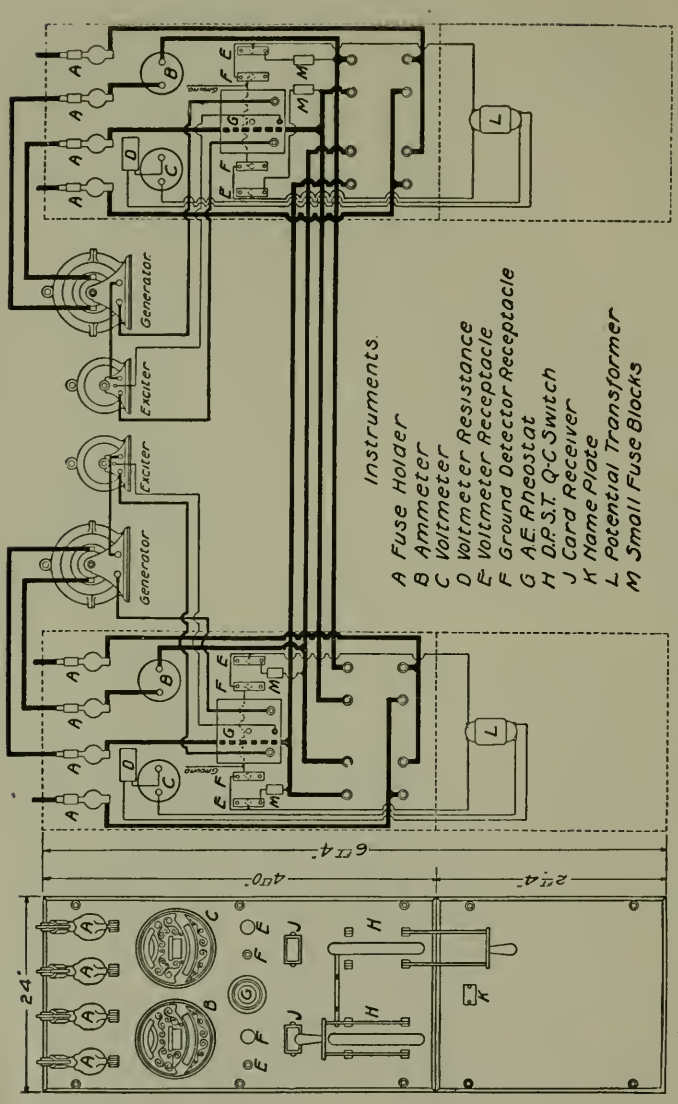


FIG. 30.—Single-phase generator and transfer panel. Rating: 7.5 to 150 kw., 1150 volts, or 15 to 300 kw., 2300 volts.

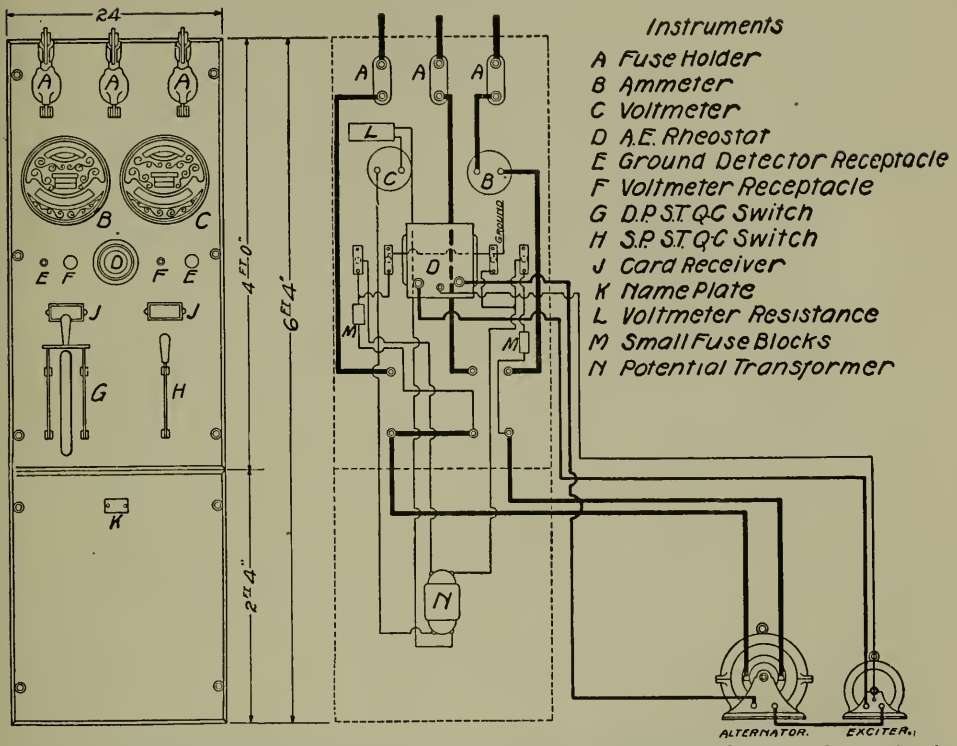


Fig. 31.—Single-phase generator panel with one incandescent lamp and one arc lamp circuit. Rating: 7.5 to 150 kw., 1150 volts, or 15 to 300 kw., 2300 volts.

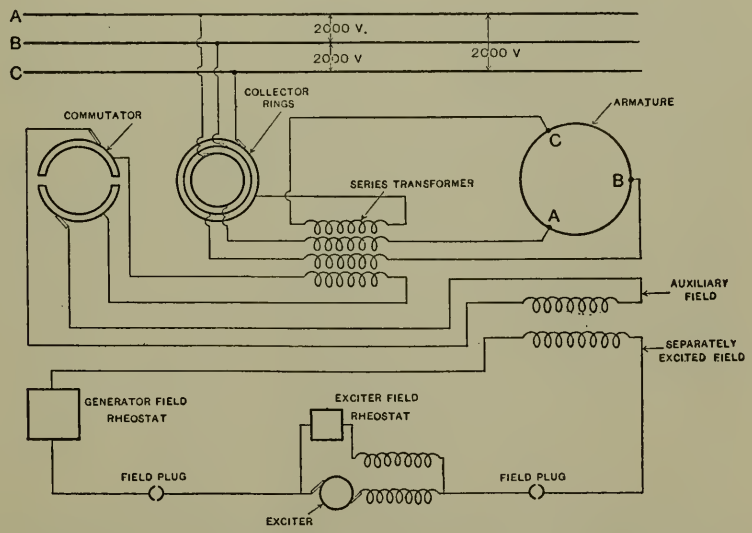


Fig. 32.—Connections of a three-phase composite-wound alternator, Westinghouse system

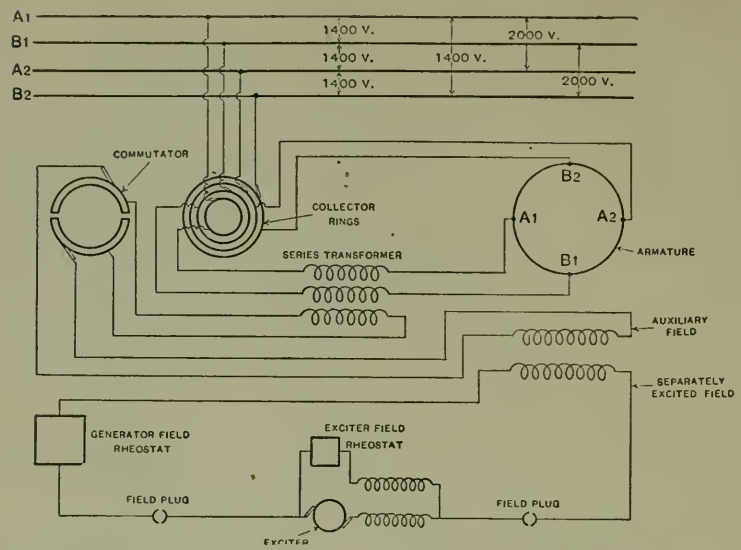


FIG. 33.—Connections of a two-phase composite-wound alternator, Westinghouse system.

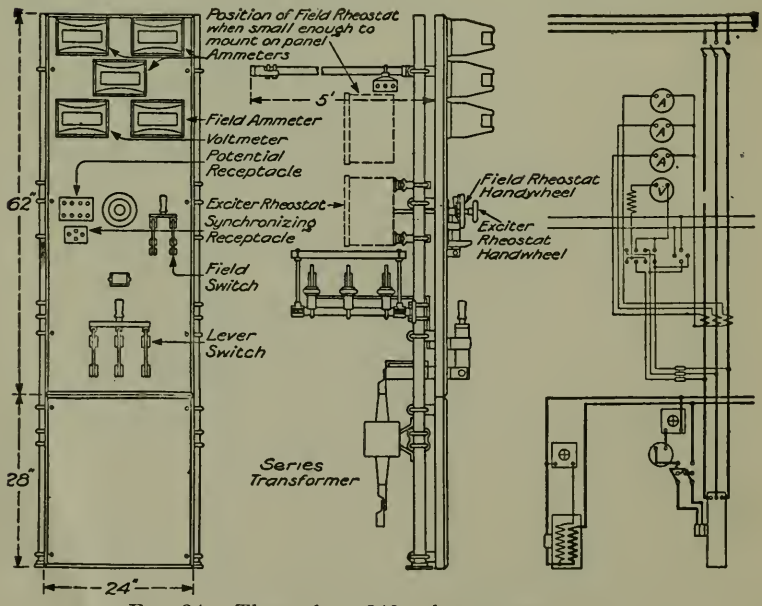


FIG. 34.—Three-phase 240-volt generator panel.

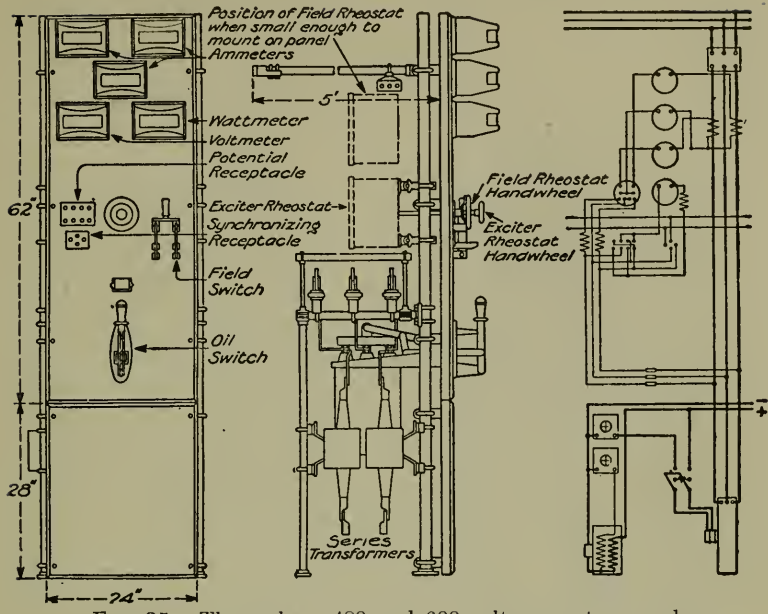


FIG. 35.—Three-phase 480 and 600-volt generator panel.

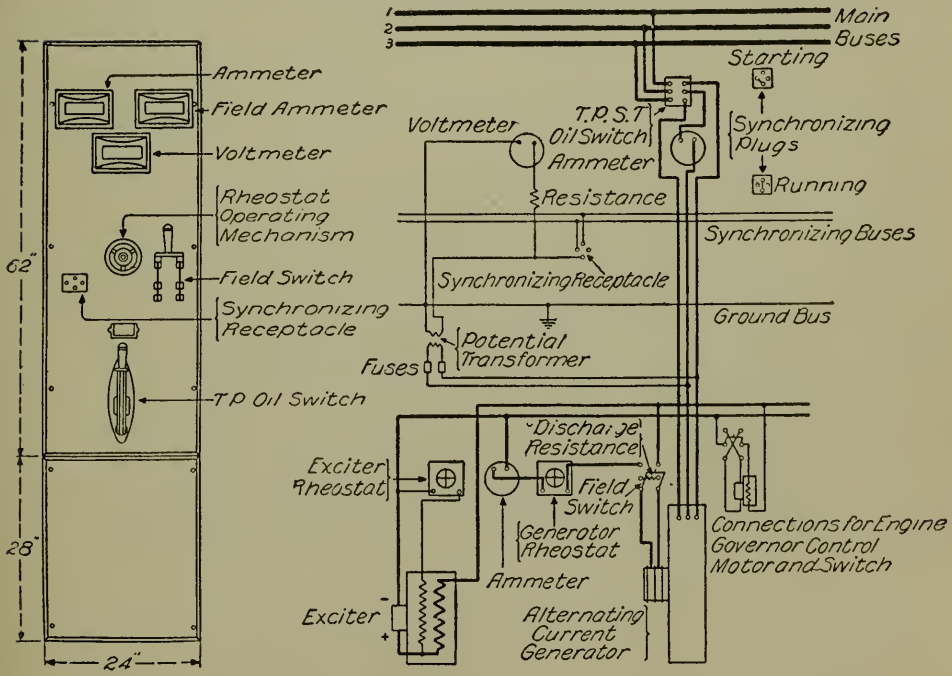


FIG. 36.—Three-phase generator panel with one ammeter. Rating: 8 to 160 amp., 1150 and 2300 volts.

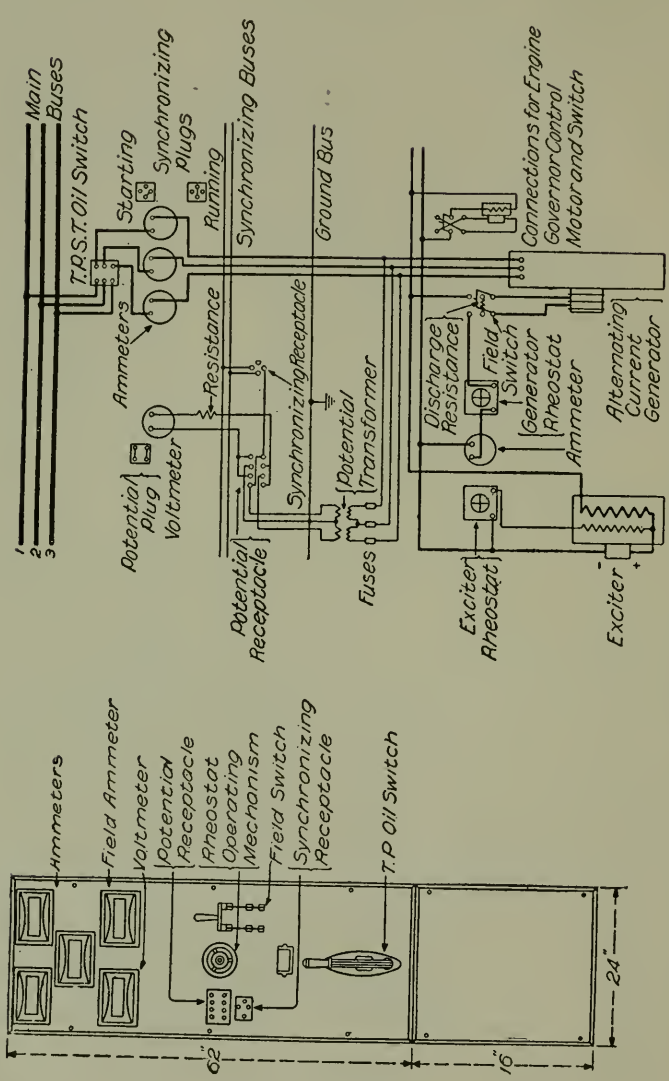


FIG. 37.—Three-phase generator panel with three main ammeters. Rating: 8 to 160 amp., 1150 and 2300 volts.

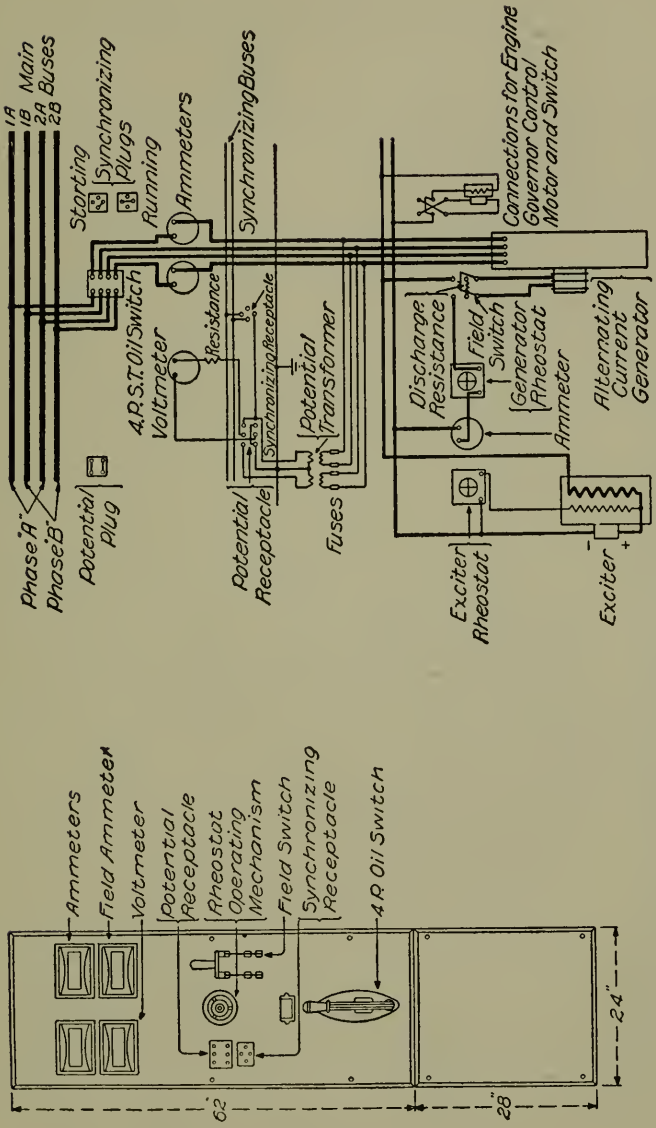


FIG. 38.—Two-phase generator panel with two main ammeters. Rating: 8 to 160 amp., 1150 and 2300 volts.

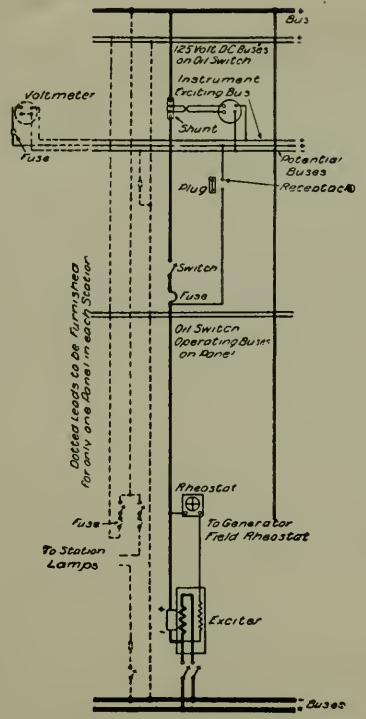


FIG. 39.—Connections for an exciter panel in a large generating station.

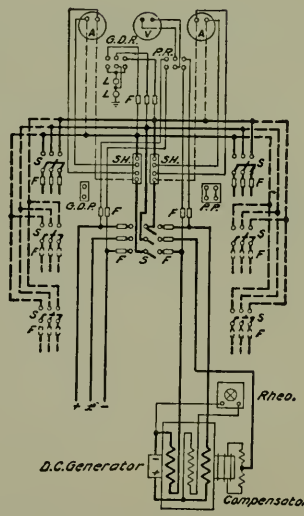


FIG. 39A.—Diagram of connections. A, ammeter; F, fuse; G.D.P., ground detector plug; G.D.R., ground detector receptacle; L, ground detector lamp; P.P., potential plug; P.R., potential receptacle; Rheo., rheostat; S.T.P.S.T., switch; S.H., shunt; V, voltmeter.

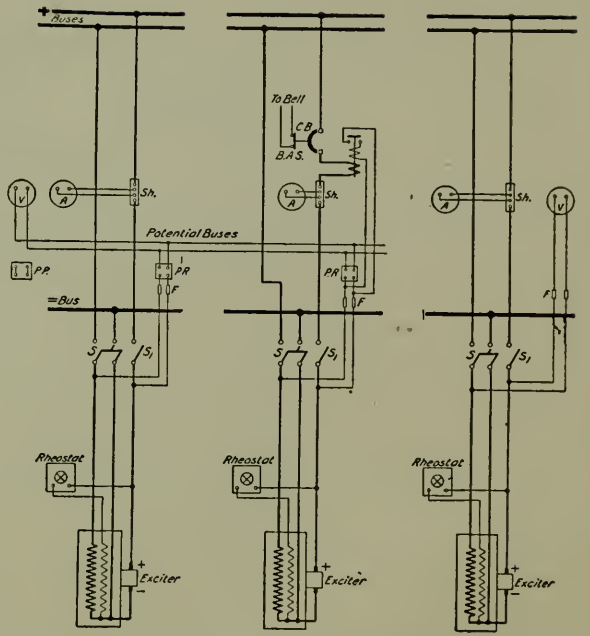


FIG. 40.—Connections of single-circuit exciter panels. A, without voltmeter or fuses; B, without voltmeter with reverse current circuit breaker; C, with voltmeter without fuses.

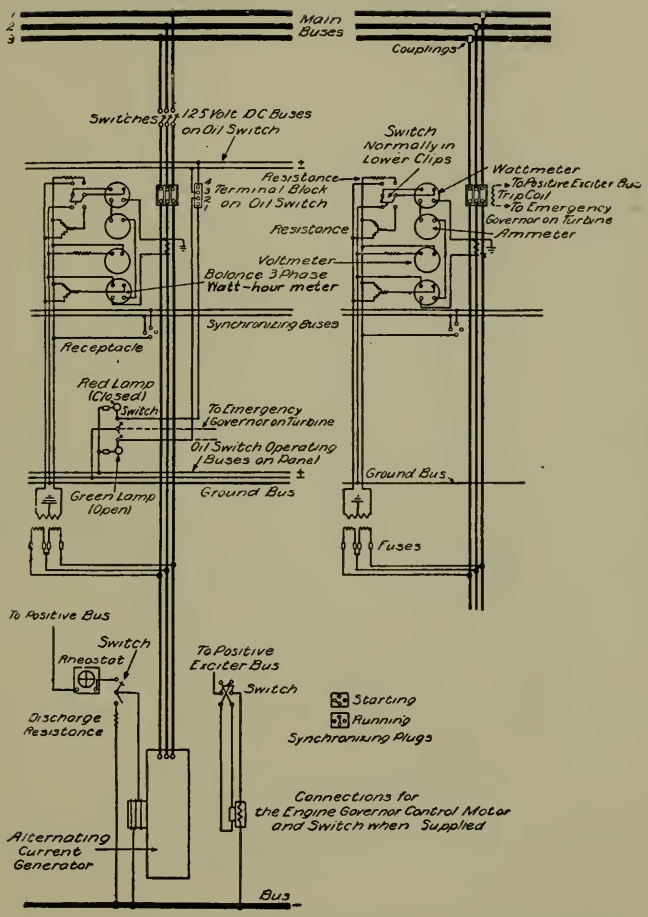


FIG. 41.—Connections for an a.c. generator panel in a large station, showing two methods of connection.

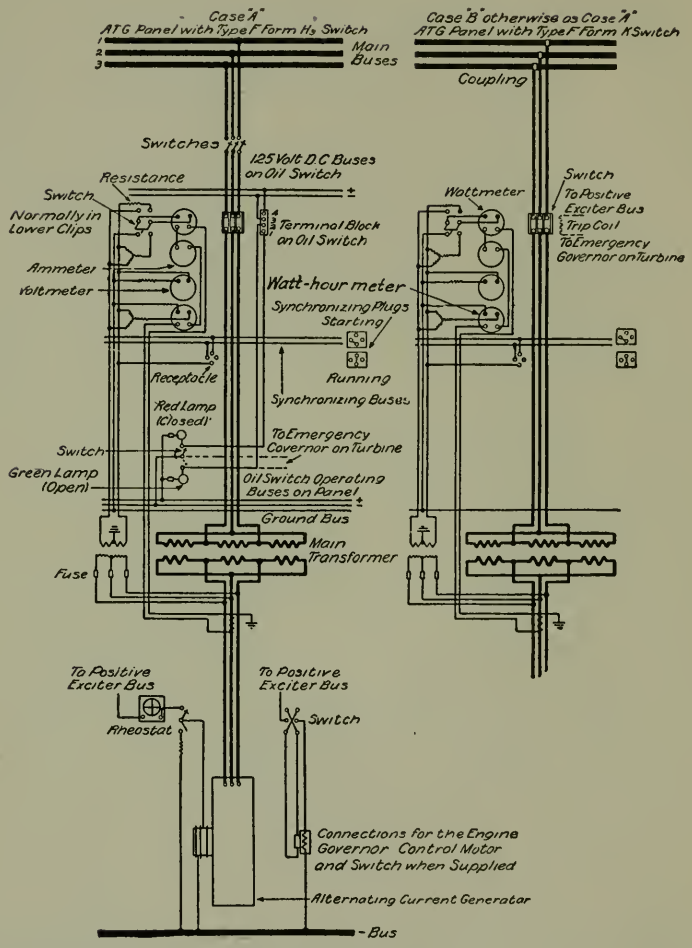


FIG. 42.—Connections for an a.c. generator panel with step-up transformers, showing two methods of connection.

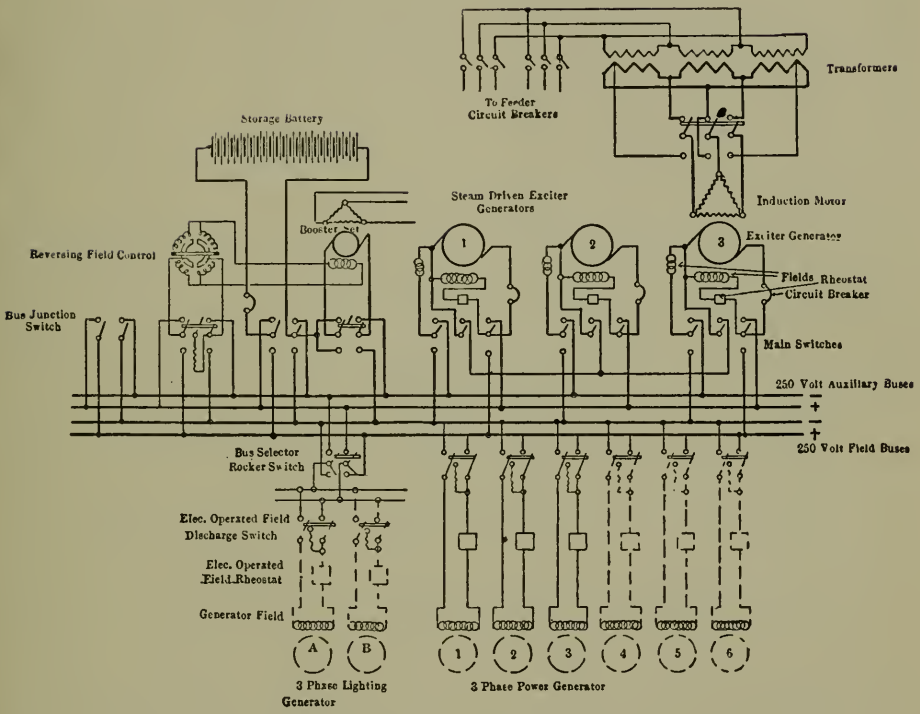


FIG. 43.—Connections of an exciting system for a large station; one motor-driven and two steam-driven exciters and a storage battery with booster.

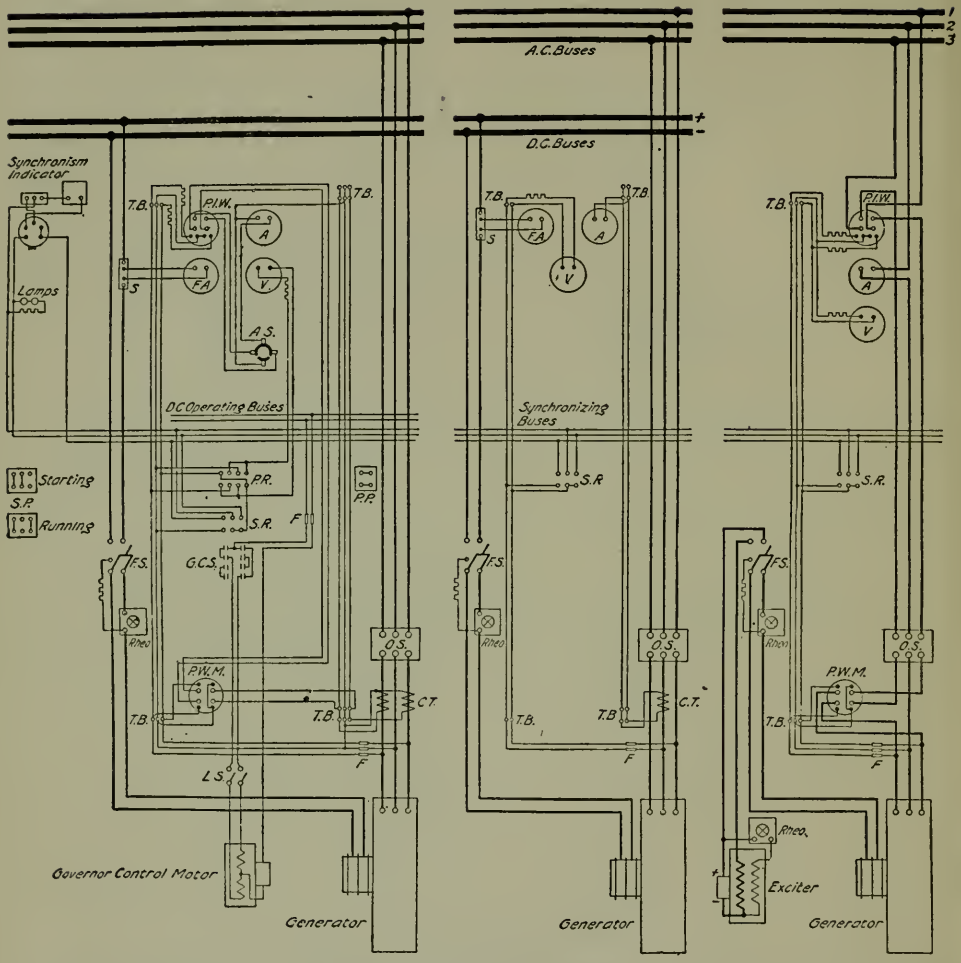


FIG. 43A.—Diagram of connections for generator panels. A, ammeter (A.C.); A.S., three-way ammeter switch; C.T., current transformer; F, fuse; F.A., field ammeter (D.C.); F.S., field switch; G.C.S., governor control switch; L.S., limit switch (included with governor motor); O.S., oil switch; P.I.W., polyphase indicating watt meter; P.W.M., polyphase watt meter; P.R., potential receptacle; P.P., potential plug; Rheo., rheostat; S, shunt (only for 80 amp. and over); S.R., synchronizing receptacle; S.P., synchronizing plugs; T.B., terminal board for instrument leads; V, voltmeter (A.C.).

SECTION III

FEEDERS

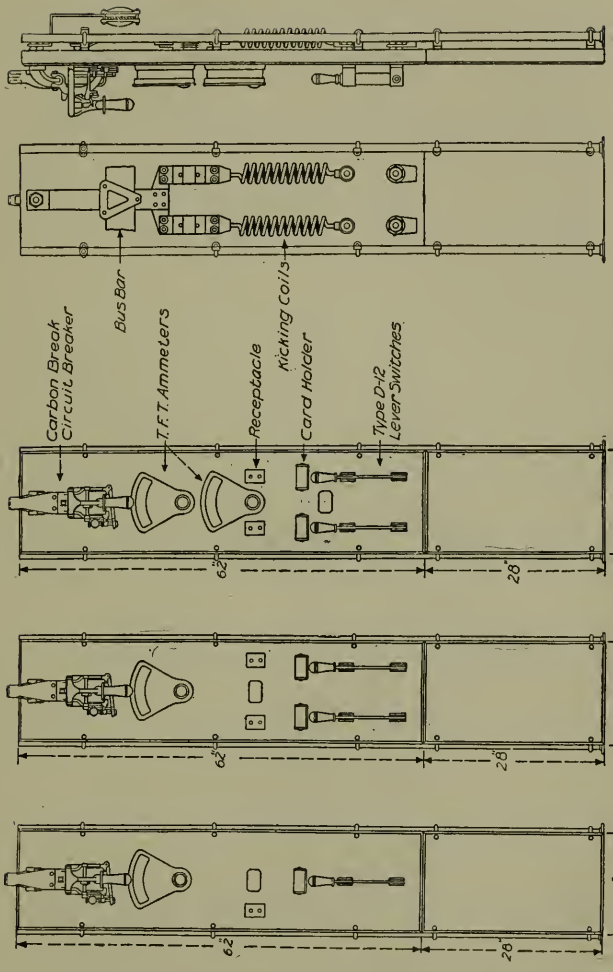


FIG. 44.—Direct-current railway feeder panels.

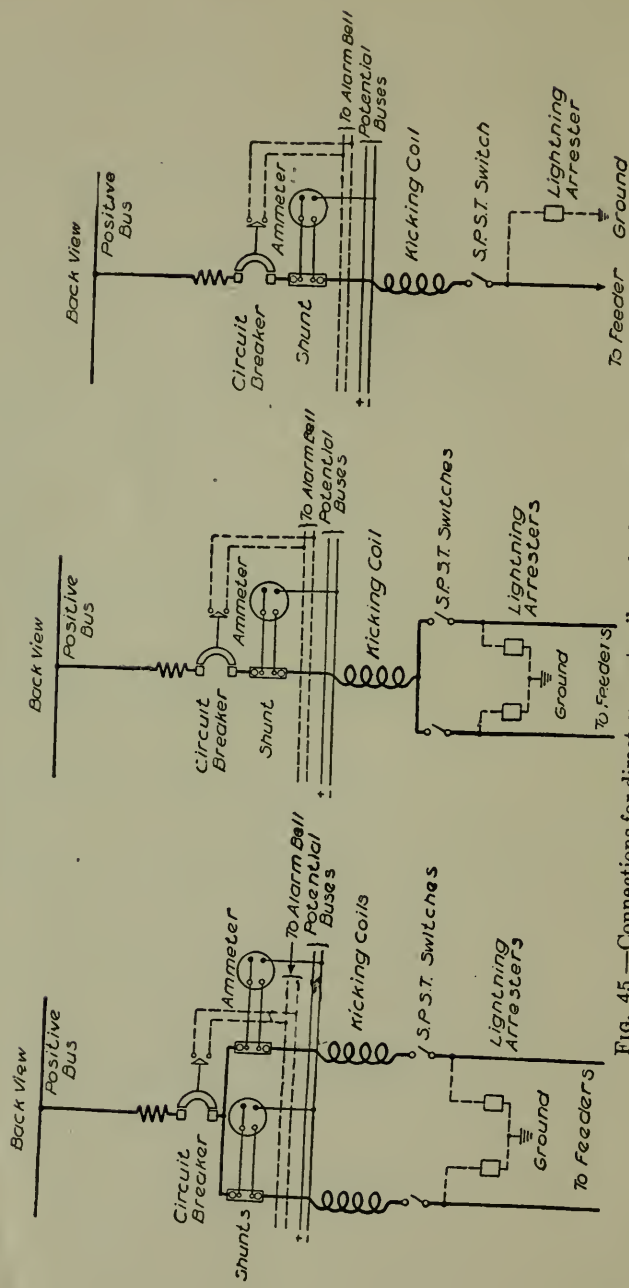


FIG. 45.—Connections for direct-current railway feeder panels shown in Fig. 44.

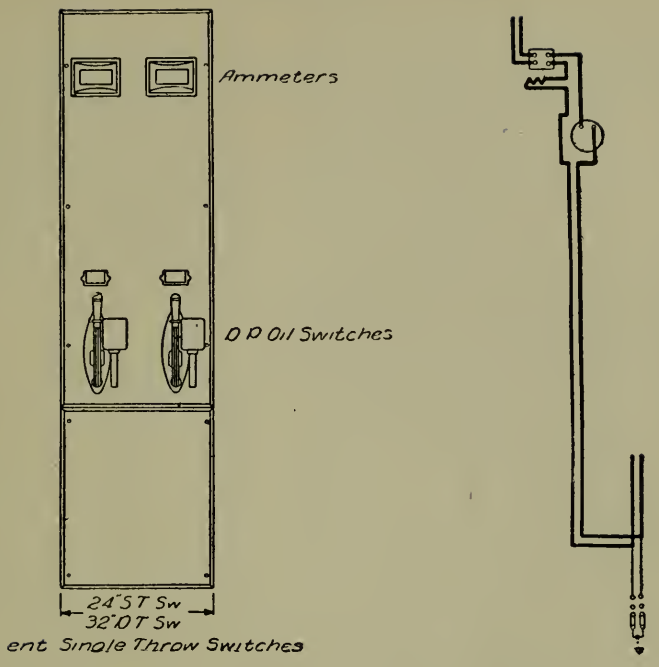


FIG. 46.—Single-phase feeder panel with automatic oil switches (double panel). Rating: 8 to 100 amp., 1150 and 2300 volts.

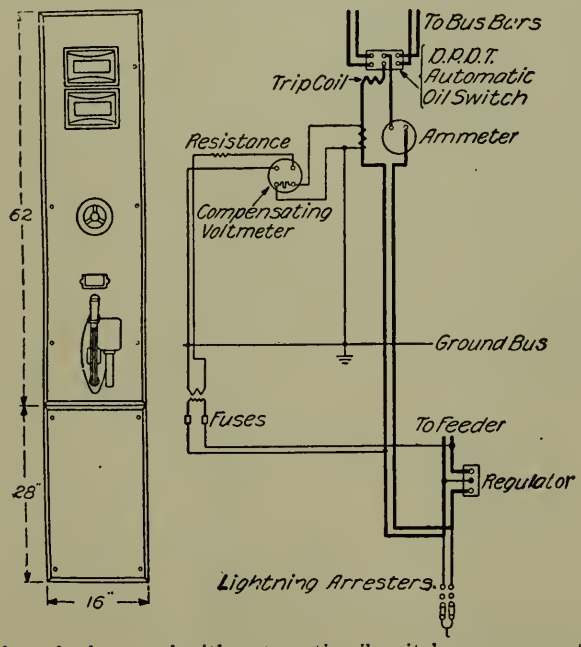


FIG. 47.—Single-phase feeder panel with automatic oil switches, compensating voltmeter and feeder regulator. Rating: 8 to 100 amp., 1150 and 2300 volts.

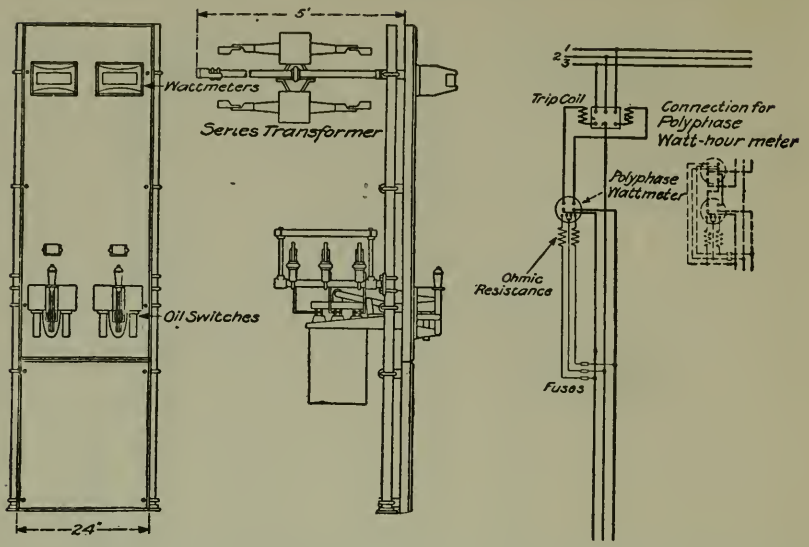


FIG. 48.—Two-circuit three-phase feeder panel with oil switches, 480 and 600 volts.

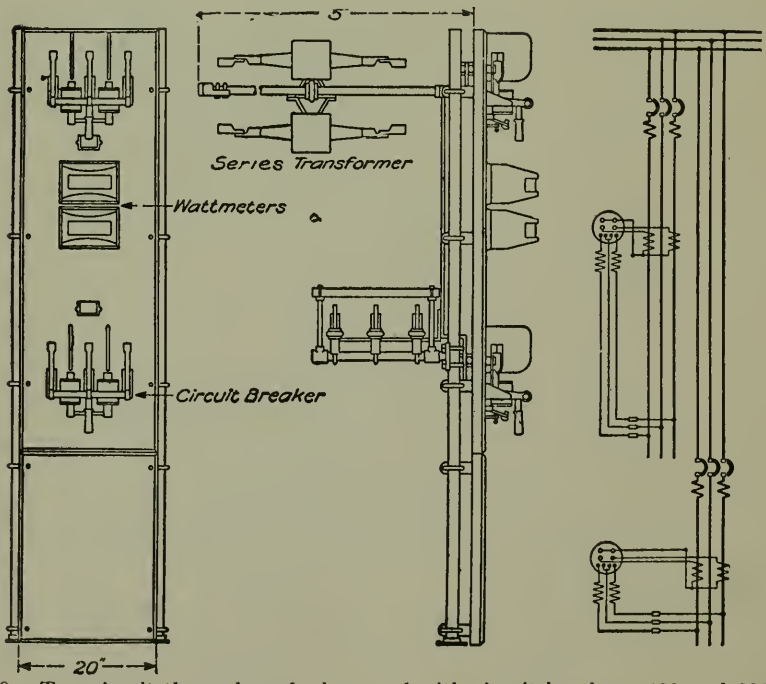


FIG. 49.—Two-circuit three-phase feeder panel with circuit breakers, 480 and 600 volts.

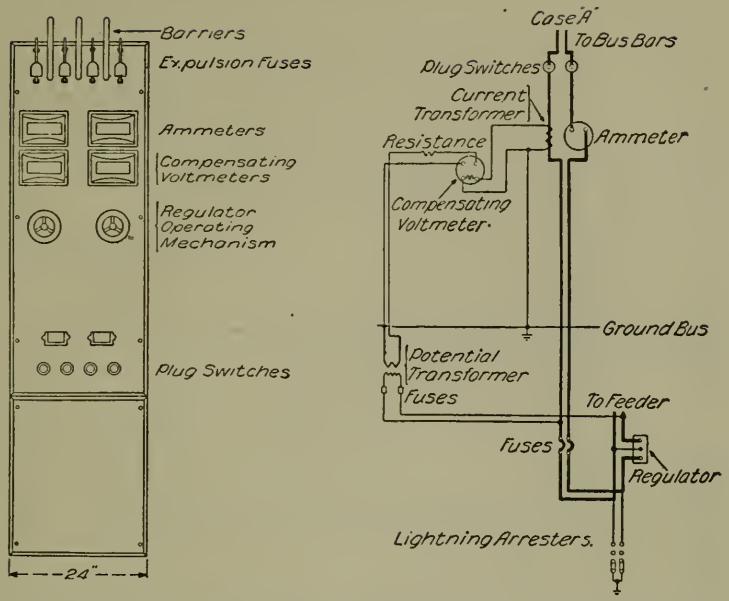


FIG. 50.—Single-phase feeder panel with plug switches, expulsion fuses, compensating voltmeter and feeder regulator (double panel). Rating: 8 to 100 amp., 1150 and 2300 volts.

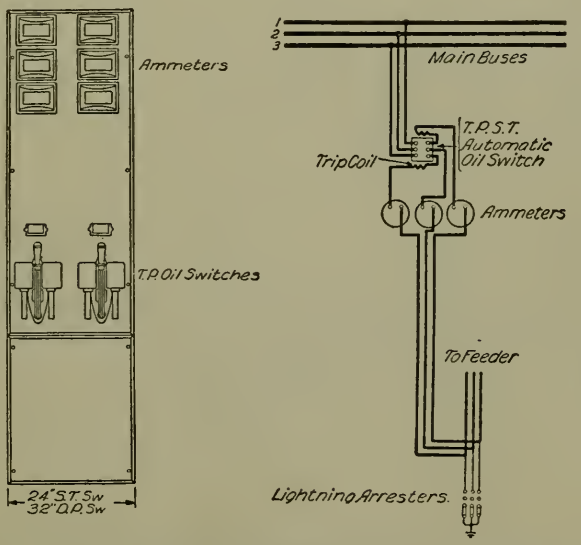


FIG. 51.—Three-phase feeder panel with automatic switches (double panel). Rating: 8 to 100 amp., 1150 and 2300 volts.

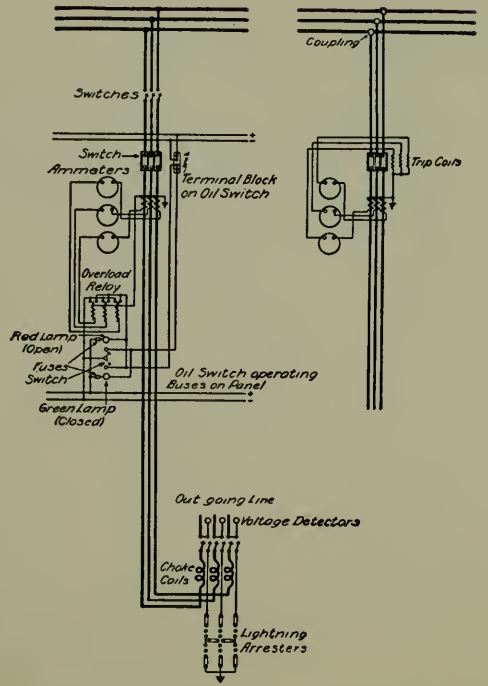


FIG. 52.—Connections for a.c. outgoing line panels, showing two systems of connection.

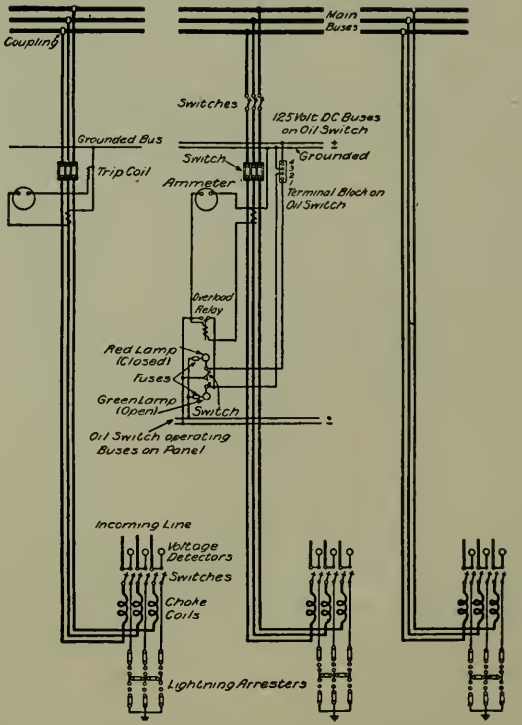


FIG. 53.—Connections for a.c. incoming line panels, showing three systems of connection.

SECTION IV

TRANSFORMERS

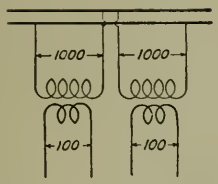


FIG. 54.—Single-phase transformers on single-phase system.

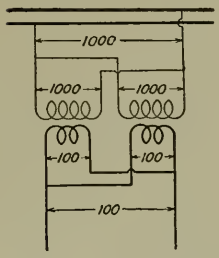


FIG. 55.—Single-phase transformers, secondaries in parallel.

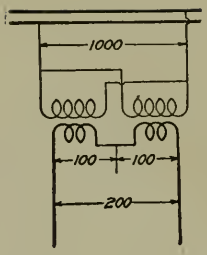


FIG. 56.—Single-phase transformers, secondaries in series.

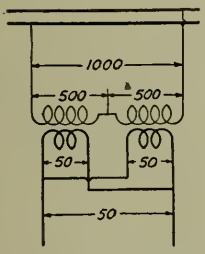


FIG. 57.—Single-phase transformer, primaries in series, secondaries in parallel.

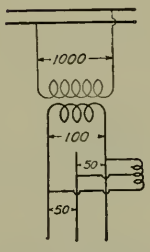


FIG. 58.—Single-phase transformer connects with balancing coil to three-wire system.

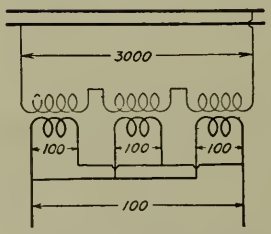
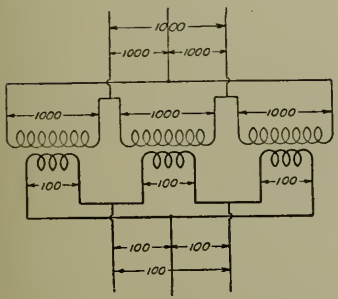


FIG. 59.—Three single-phase transformers, primaries in series, secondaries in parallel.



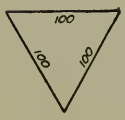


FIG. 60.—Three single-phase transformers connected delta-delta to a three-phase system.

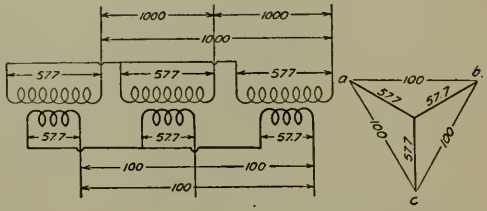


FIG. 61.—Three single-phase transformers connected star-star to a three-phase system.

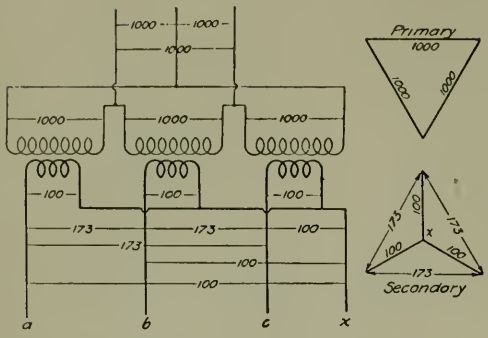


FIG. 62.—Three single-phase transformers connected delta-star to a three-phase system.

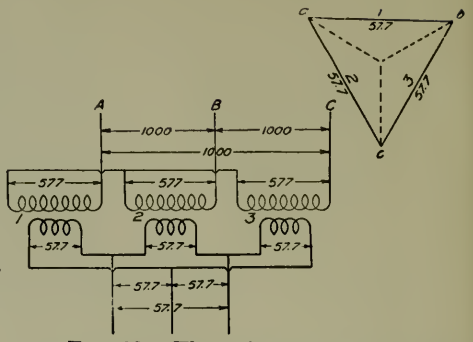
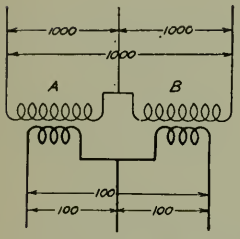


FIG. 63.—Three single-phase transformers connected star-delta to a three-phase system.



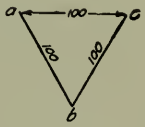
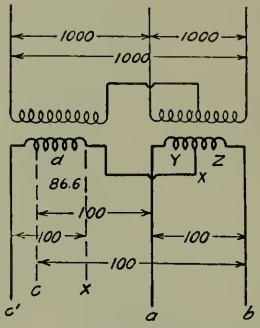


FIG. 64.—Two single-phase transformers connected open delta to a three-phase system.



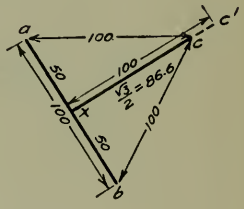
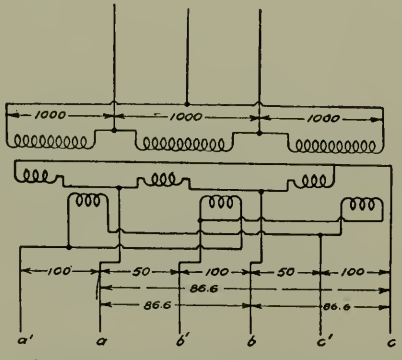


FIG. 65.—Two single-phase transformers connected tee to a three-phase system.



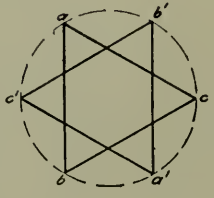


FIG. 66.—Three single-phase transformers with two-coil secondaries connected double-delta to a three- to six-phase system.

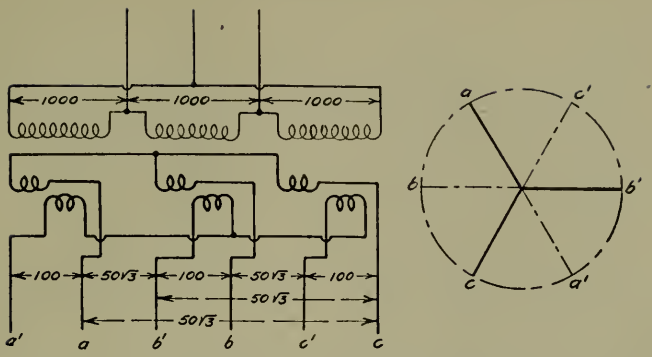


FIG. 67.—Three single-phase transformers with two-coil secondaries connected double-star to a three- to six-phase system.

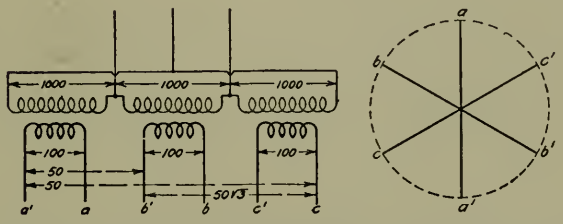


FIG. 68.—Three single-phase transformers connected diametrically to a three- to six-phase system.

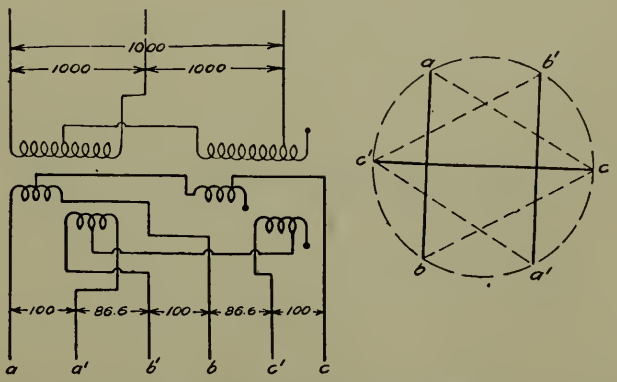


FIG. 69.—Two single-phase transformers with two-coil secondaries connected tee to a three- to six-phase system.

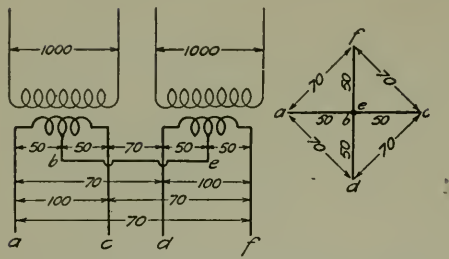


FIG. 70.—Two single-phase transformers connected star to a four-wire two-phase system.

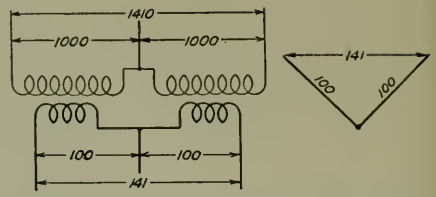


FIG. 71.—Two single-phase transformers connected to a three-wire two-phase system.

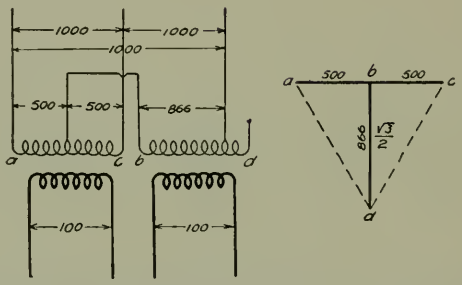


FIG. 72.—Two single-phase transformers connected tee to a three-phase two-phase system (Scott system).

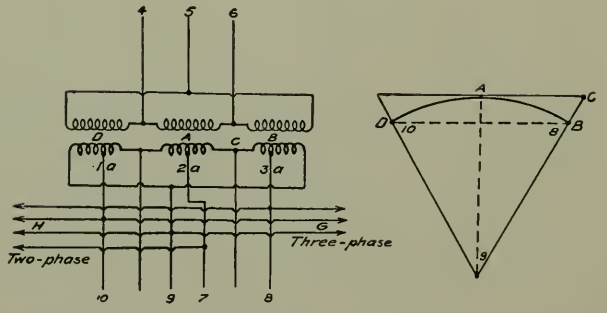


FIG. 73.—Three single-phase transformers connected delta to three-three two-phase system (Taylor system). Both- two and three-phase can be taken off the secondary leads. Motors used on the two-phase system cannot have inter-connected windings.

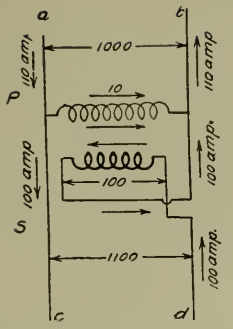


FIG. 74.—Single-phase transformer used as a booster.

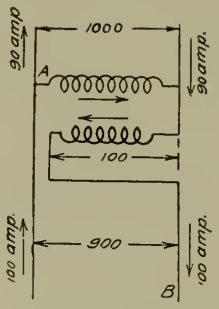


FIG. 75.—Single-phase transformer connected to lower the e.m.f.

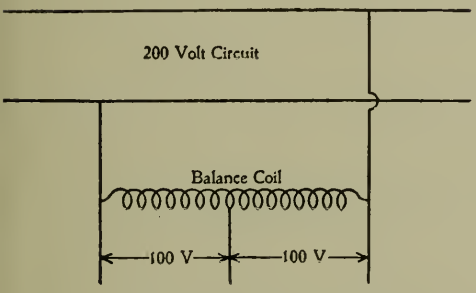


FIG. 76.—Auto-transformer used as a balance coil for deriving of three-wire system from a two-wire system. Three-wire voltage one-half the main voltage.

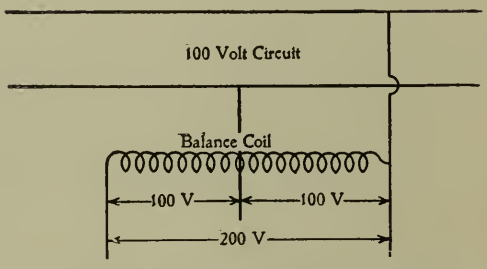


FIG. 77.—Auto-transformer used as a balance coil for deriving of three-wire system from a two-wire system. Three-wire voltage same as main voltage.

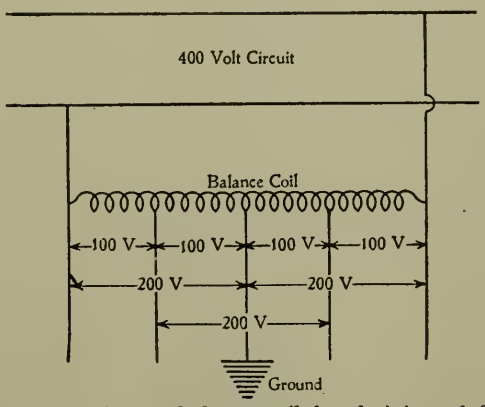


FIG. 78.—Auto-transformer used as a balance coil for deriving of five-wire system from a two-wire system.

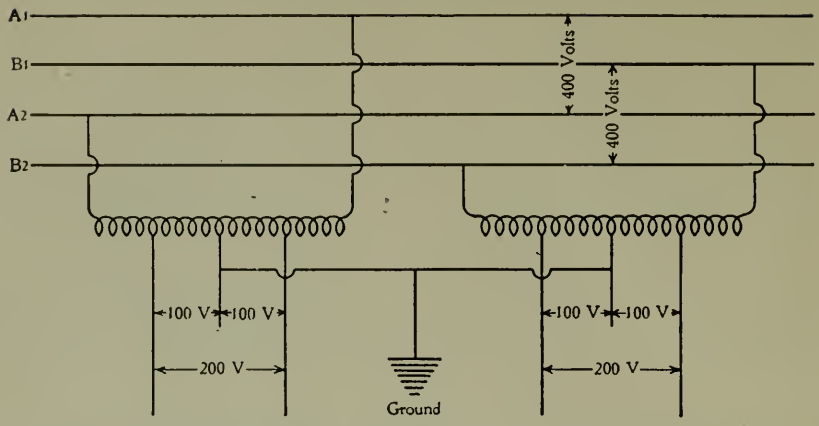


FIG. 79.—Two five-tap auto-transformers connected to two-phase primary circuit to obtain 100 and 200 volt, two-phase secondary circuits.

SECTION V

POTENTIAL REGULATORS

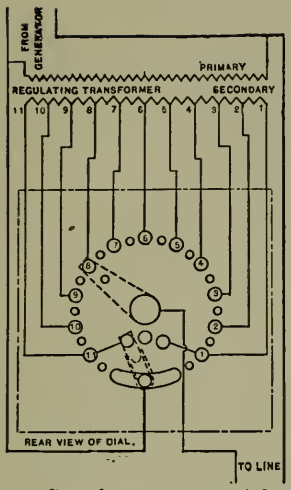


FIG. 80.—Step-by-step potential regulating transformer. By throwing the switch at the bottom, the transformer can be made to boost or lower the line voltage. See Figs. 74 and 75.

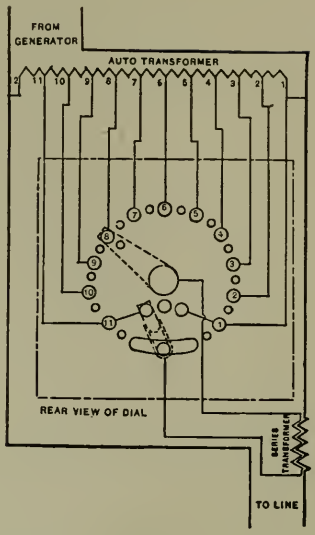


FIG. 81.—Step-by-step potential regulating transformer for large currents. The exciter voltage is added or subtracted through a series transformer.

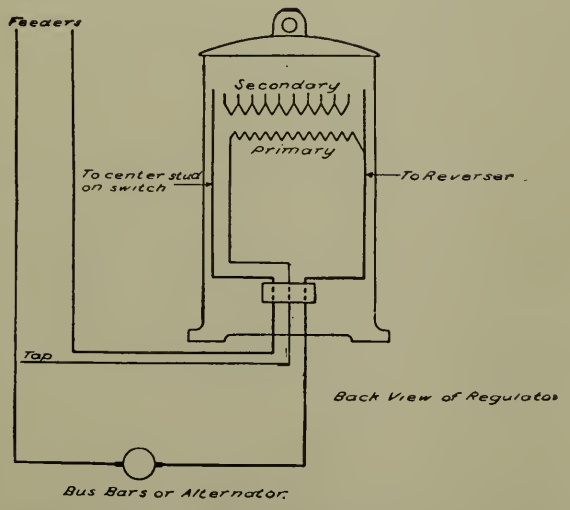


FIG. 82.—External connections of a variable-ratio potential regulating transformer operated by a dial switch.

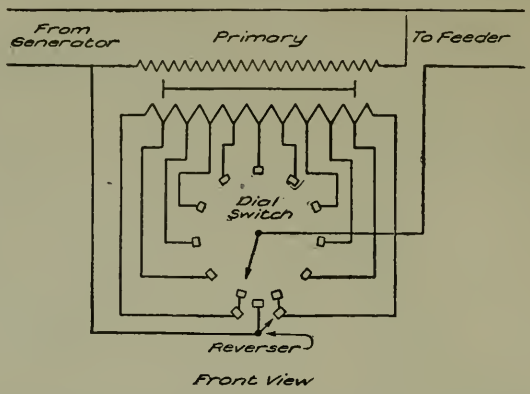


FIG. 83.—Internal connections of the regulating transformer shown in Fig. 84. The transition from maximum boost to maximum lower, takes place in a definite number of steps. There being no air gap, the power-factor is practically unity. The contact arm is equipped with a quick-break contact to prevent sparking and fluctuation in the feeder voltage during the transition from one contact to the next.

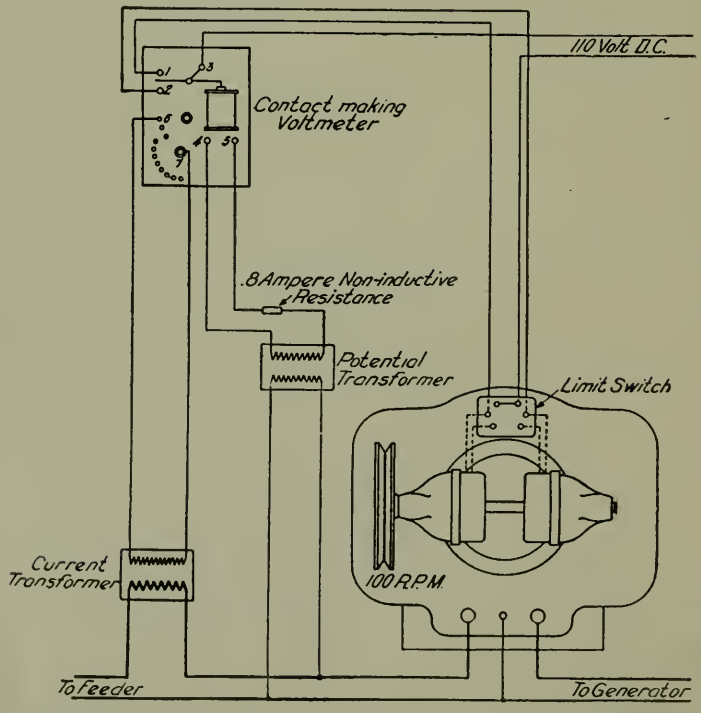


FIG. 84.—External connections of a variable-ratio potential regulating transformer for operation by an automatically controlled dial switch. For connections of the contact-making voltmeter, see Fig. 88.

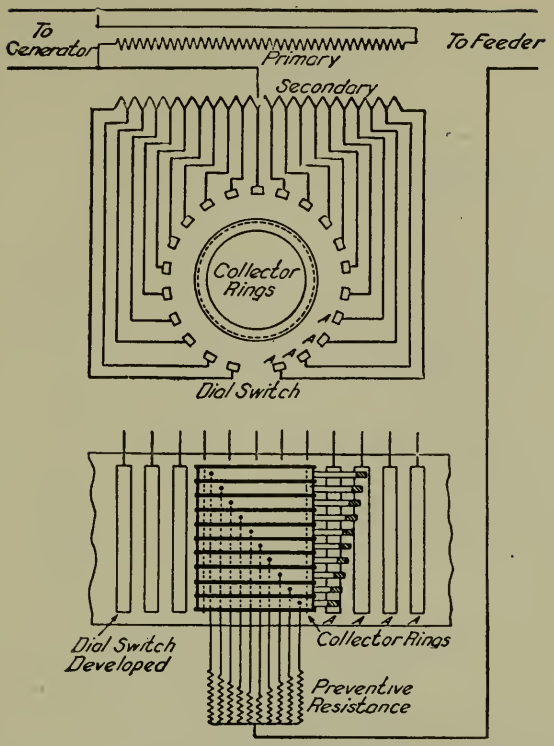


FIG. 85.—Internal connections of the regulating transformer shown in Fig. 84. Resistances inserted between the contacts to prevent sparking.

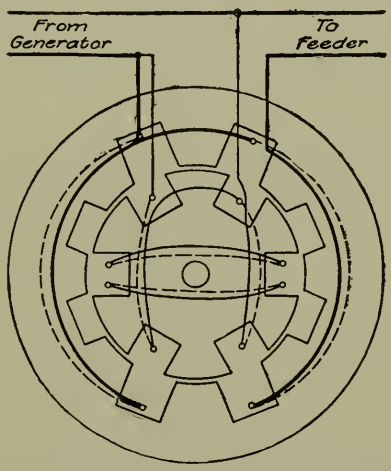


FIG. 86.—Connection of the windings of a single-phase induction potential regulator. Rotor in position to generate the maximum secondary e.m.f. The principle of the induction regulator is the same as that of the transformer type, except that the transition from maximum boost to maximum lower is smooth and continuous, being obtained by mechanical displacement of the primary and secondary coils of the transformer. The power-factor of this type is about 0.85.

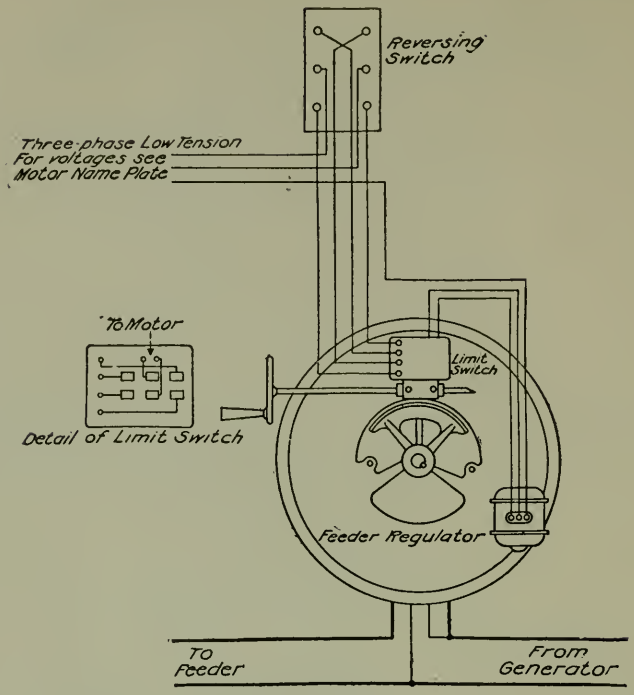


FIG. 87.—External connections of a single-phase induction potential regulator operated by a hand-controlled three-phase induction motor.

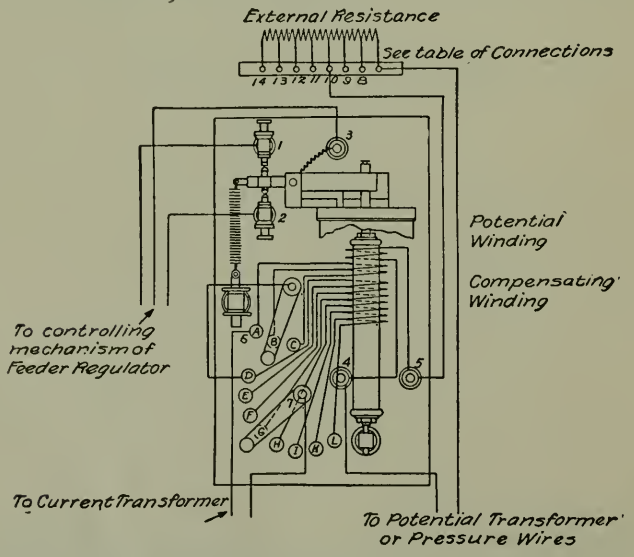

External Resistance
See table of Connections
14 13 12 11 10 9 8
Potential Winding
Compensating Winding
To controlling mechanism of Feeder Regulator
To Current Transformer
To Potential Transformer or Pressure Wires

FIG. 88.—Connections of a contact-making voltmeter used to operate the relay switch of an automatically controlled potential regulator.

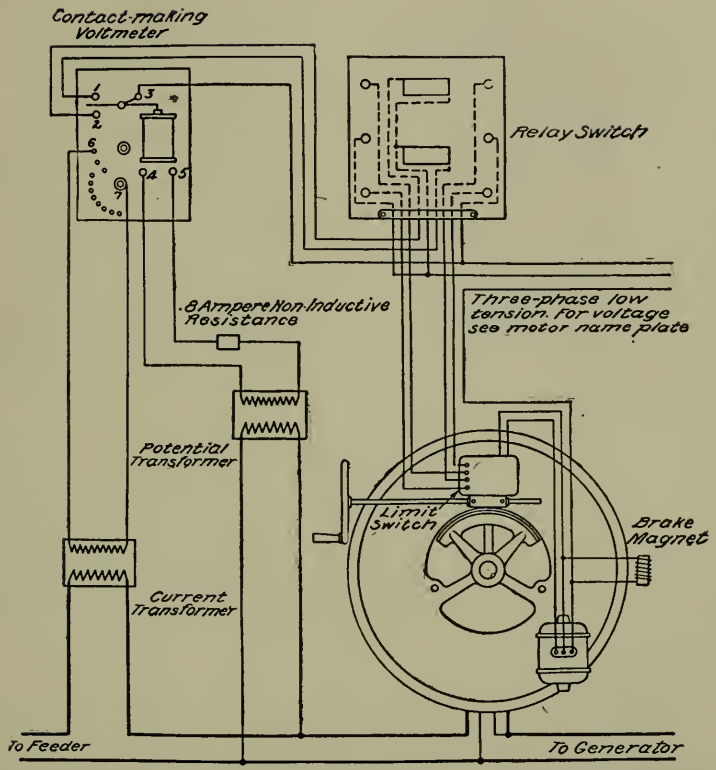
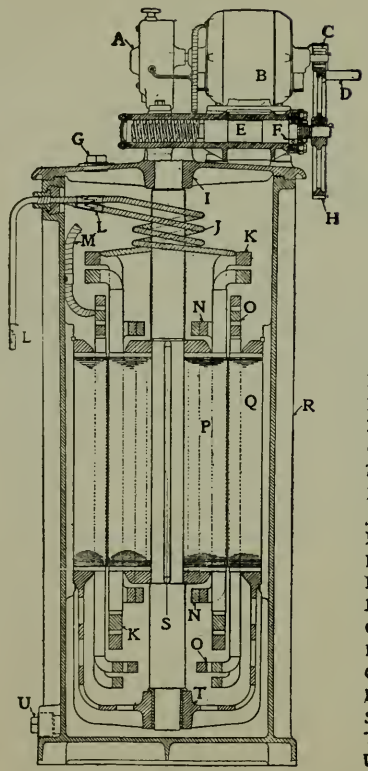
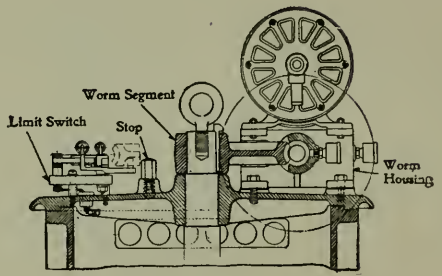


FIG. 89.—Connections of a single-phase induction potential regulator operated by an automatically controlled three-phase induction motor. Connections for the limit switch shown in Fig. 87. Those for the contact-making voltmeter, in Fig. 88.



A - Brake
B - Motor
C - Pinion
D - Handle
E - Worm
F - Ball bearing end thrust
G - Plug for fitting tank
H - Gear
I - Top cover
J - Primary Leads
K - Primary Winding
L - Primary Connectors
M - Secondary Leads
N - Short Circuited Winding
O - Secondary Winding
P - Primary iron Core
Q - Secondary iron Core
R - Cast iron Case
S - Shaft
T - Lower Bearing Bracket
U - Plug for draining tank



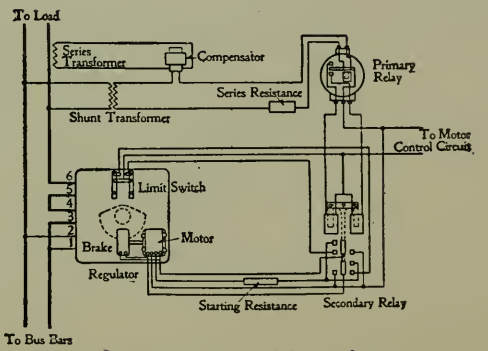


FIG. 90.—The mechanical construction and connections of an induction potential regulator.

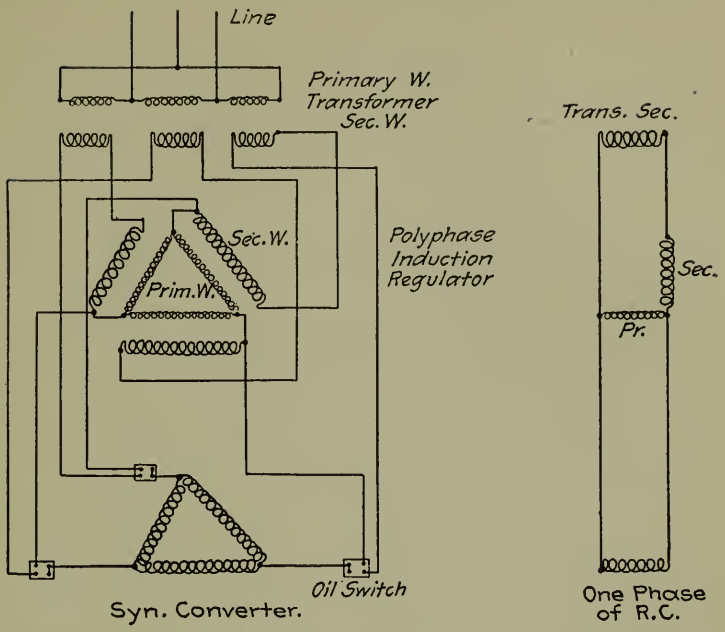


FIG. 91.—Connection of a three-phase synchronous converter to a polyphase induction regulator.

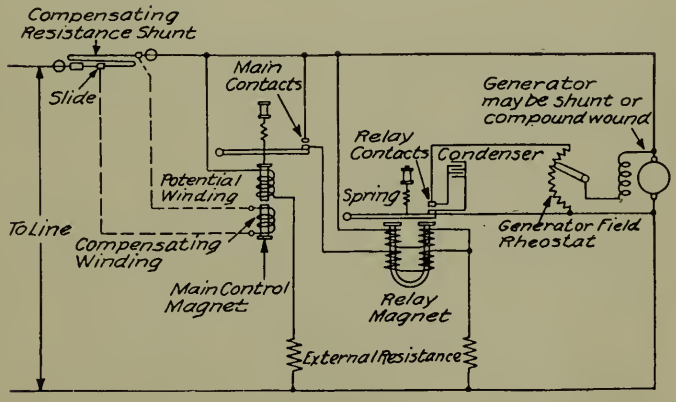


FIG. 92.—Connection of a Tirrill regulator for a direct-current generator. Regulation of the current in the generator field winding is obtained by periodically short-circuiting the field rheostat. Rising voltage inserts the rheostat into the circuit, while the falling voltage short-circuits it. In operation, the short-circuiting contact is in continuous vibration.

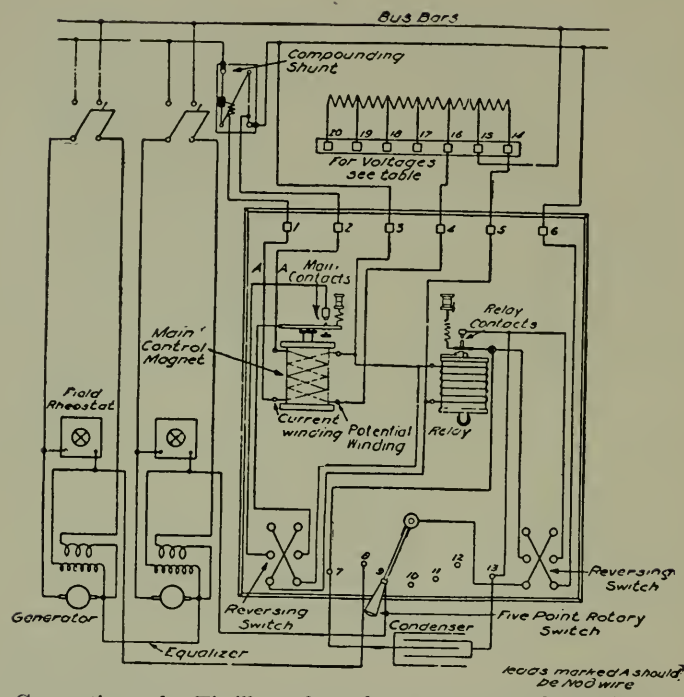


FIG. 93.—Connections of a Tirrill regulator for two compound machines, one of which is a reserve unit. The regulator can be operated on either one, but not on both at the same time. Several compound-wound generators can be connected in parallel and the regulator used on one. The regulated machine will take the fluctuations, and the equalizers will divide the load properly among the rest. When used for several generators in parallel it will not compensate for line drop.

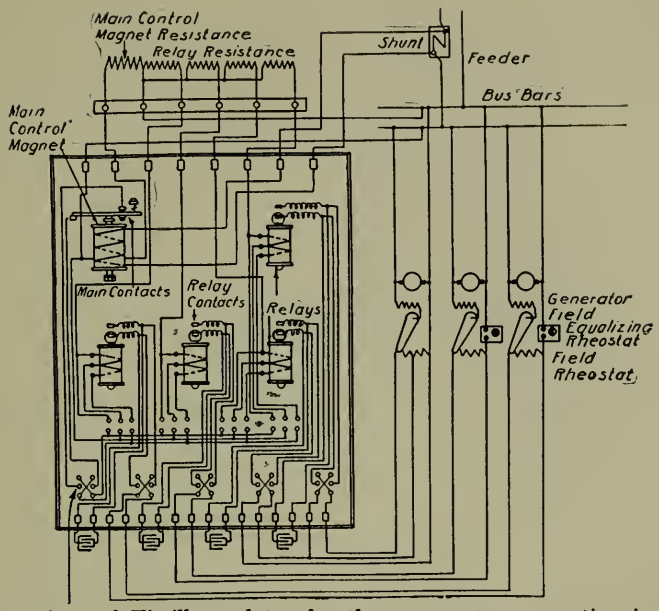


FIG. 94.—Connections of Tirrill regulator for three generators operating in parallel. The regulator is equipped with four relays and will compensate for line drop.

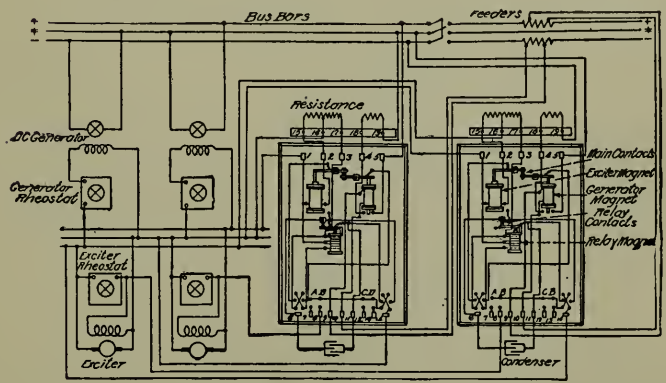


FIG. 95.—Connections of two Tirrill regulators for controlling separately excited generators connected in parallel on a three-wire system. This system permits the compensation for line drop when using any number of generators in parallel.

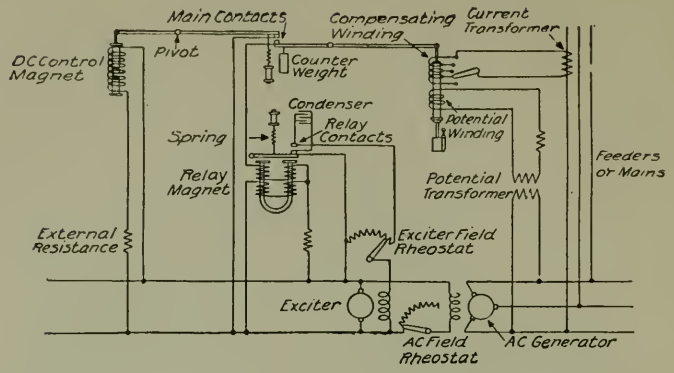


FIG. 96.—Connections of a Tirrill regulator for small or medium size exciter.

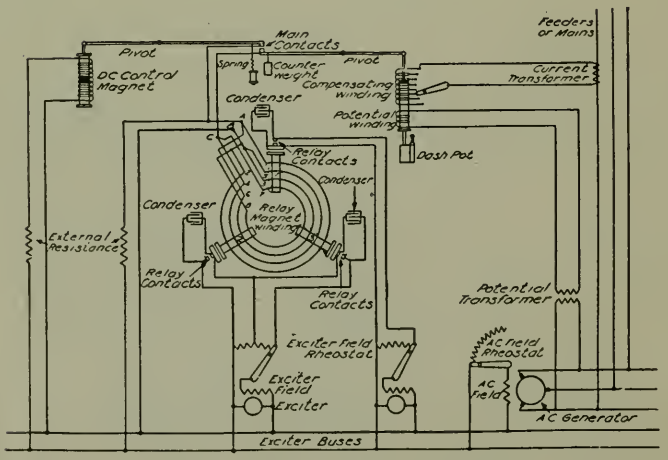


FIG. 97.—Connections of a Tirrill regulator for two exciters, one of which is larger than the other. Regulator equipped with three relays.

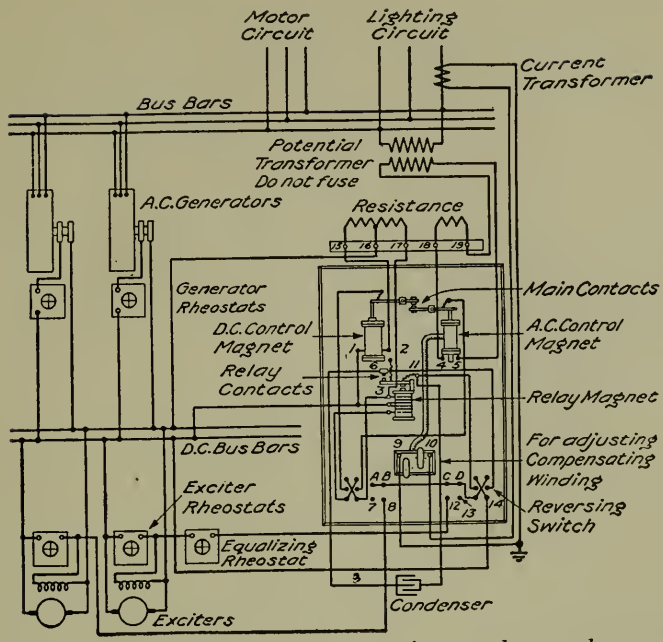


FIG. 97A.—Tirrill regulator with two exciters and several generators.

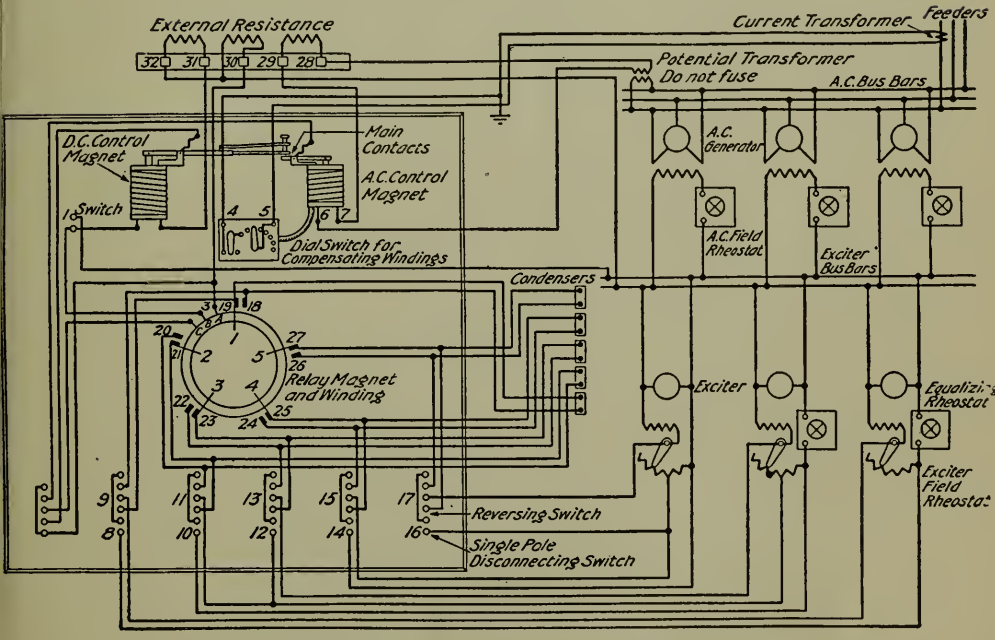


FIG. 97B.—Tirrill regulator with three exciters and several generators.

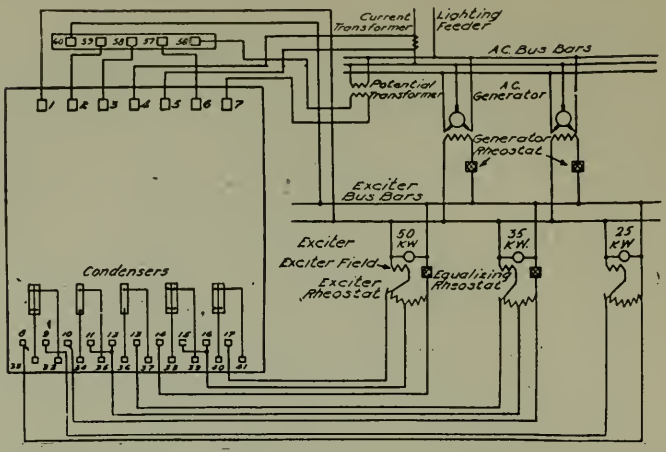


Fig. 98.—External connections of a Tirrill regulator for three exciters. The regulator is equipped with five relays.

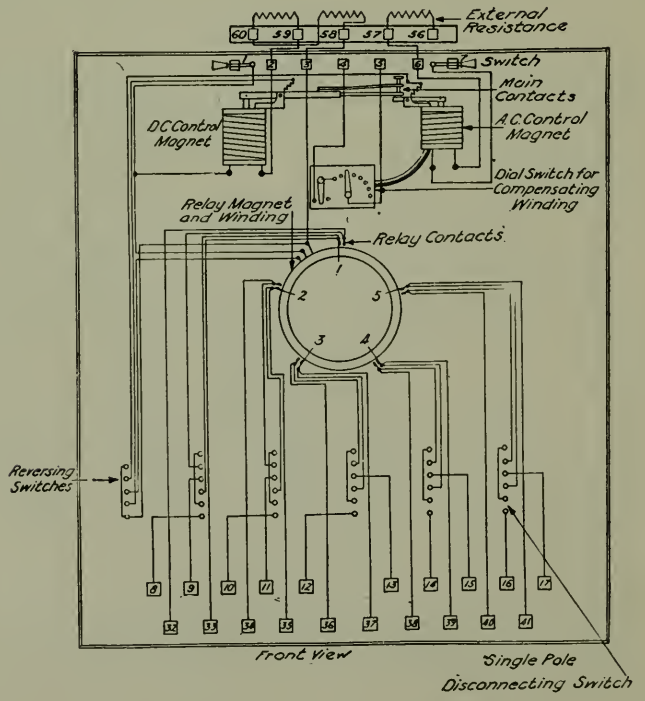


Fig. 99.—Internal connections of the Tirrill regulator shown in Fig. 98.

SECTION VI

SYNCHRONOUS CONVERTERS

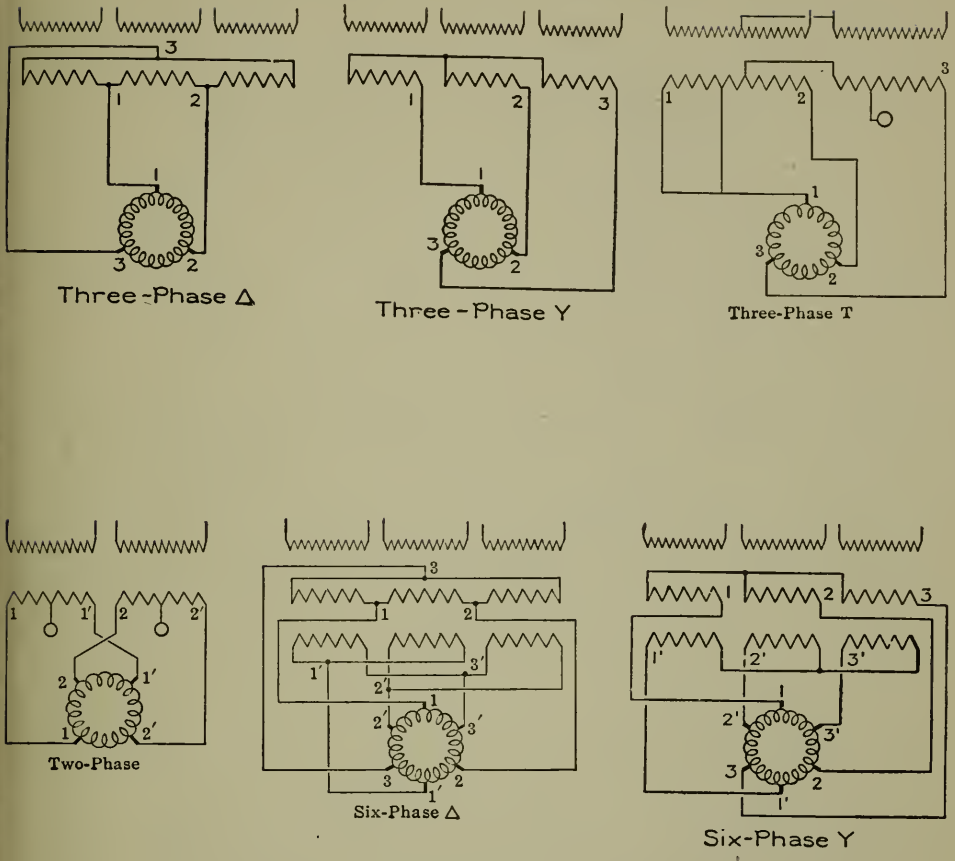


FIG. 100.—Methods of connecting transformers to synchronous converters.

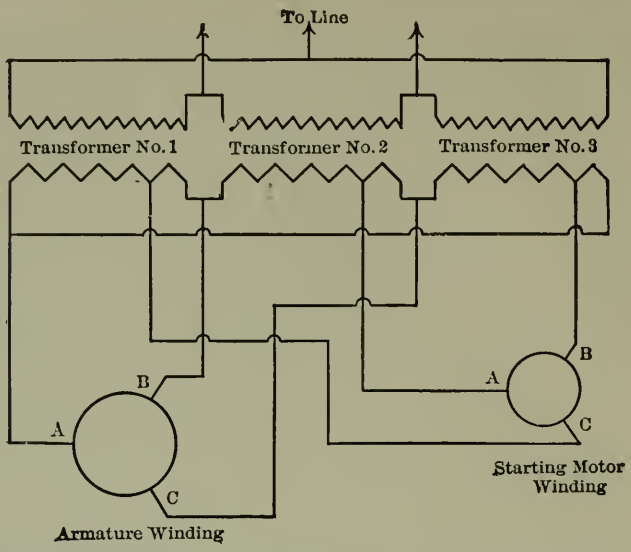


FIG. 101.—Delta-delta transformer connections for synchronous converter with induction starting motor.

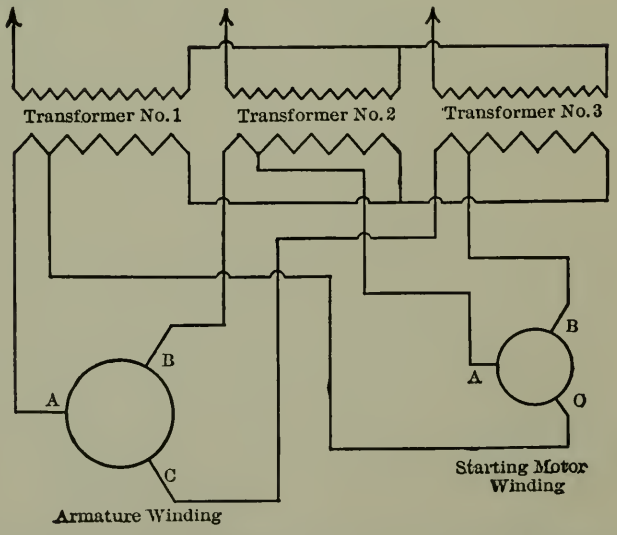


FIG. 102.—Star-star transformer connections for synchronous converter with induction starting motor.

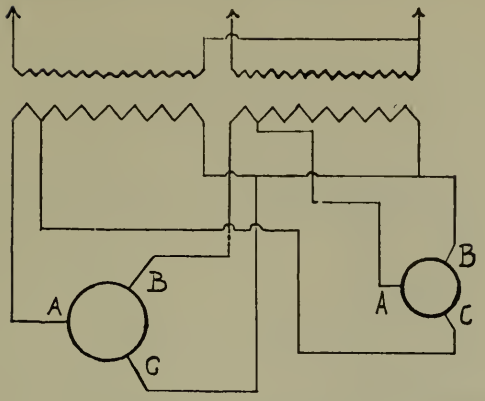


FIG. 103.—Two-phase three-wire transformer connections for synchronous converter with induction starting motor.

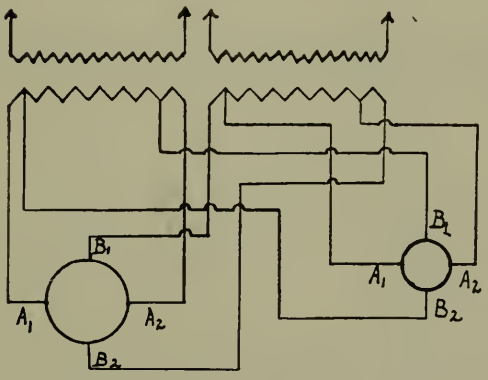


FIG. 104.—Two-phase four-wire transformer connections for synchronous converter with induction starting motor.

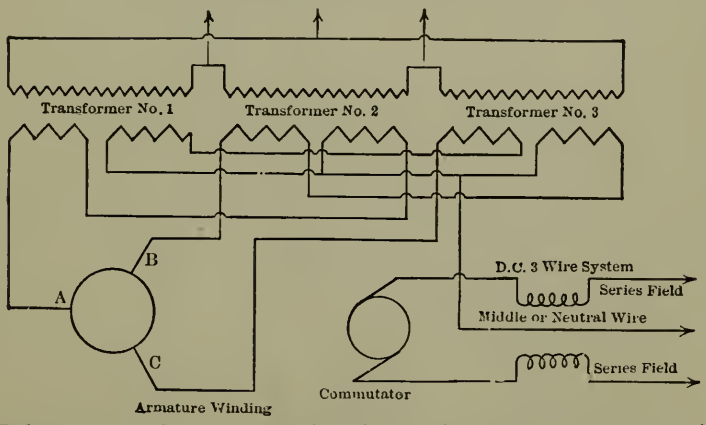


FIG. 105.—Delta-star transformer connections for synchronous converter operating on three-wire system.

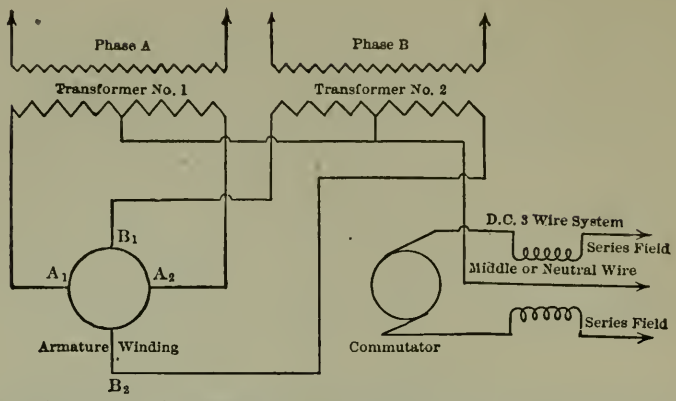


FIG. 106.—Two-phase four-wire transformer connections for synchronous converter operating on a three-wire system.

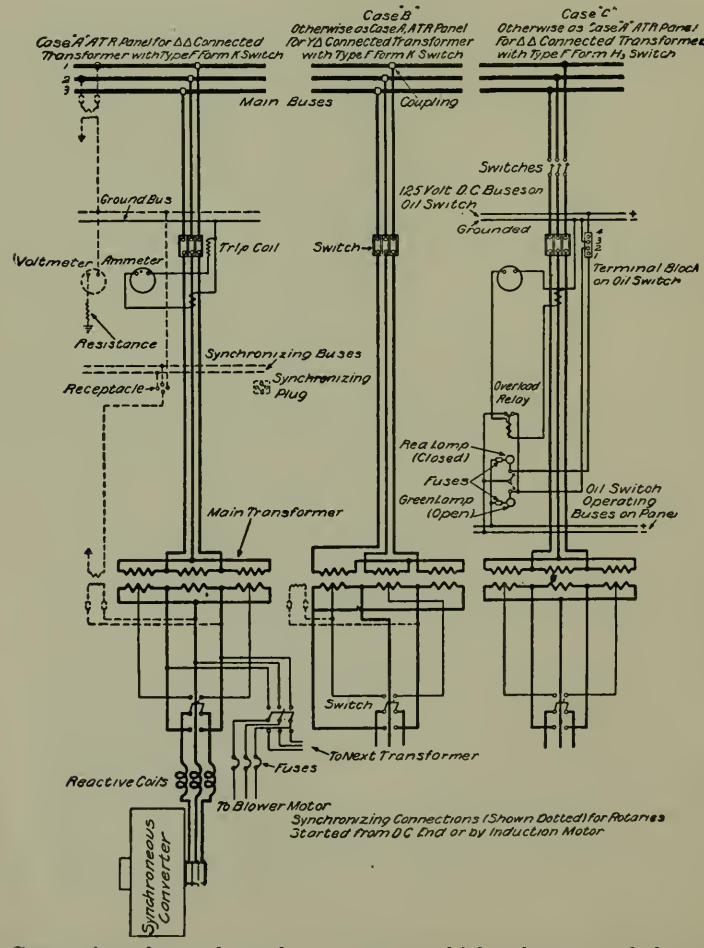

Case "A" A.T.R. Panel for ΔΔ Connected Transformer with Type F Form K Switch
Case "B" Otherwise as Case A, A.T.R. Panel for YΔ Connected Transformer with Type F Form K Switch
Case "C" Otherwise as Case "A" A.T.R. Panel for ΔΔ Connected Transformer with Type F Form H3 Switch
Main Buses
Coupling
Switches
125 Volt D.C. Buses on Oil Switch
Ground Bus
Grounded
Trip Coil
Switch
Voltmeter
Ammeter
Terminal Block on Oil Switch
Resistance
Synchronizing Buses
Receptacle
Synchronizing Plug
Overload Relay
Red Lamp (Closed)
Fuses
Green Lamp (Open)
Oil Switch Operating Buses on Panel
Main Transformer
Switch
To Next Transformer
Fuses
Reactive Coils
To Blower Motor
Synchronizing Connections (Shown Dotted) for Polarex Started from D.C. End or by Induction Motor
Synchroneous Converter

FIG. 107.—Connections for a three-phase converter, high-voltage panel, low-voltage panel, starting panel and blower-motor panel. Showing three methods of connection.

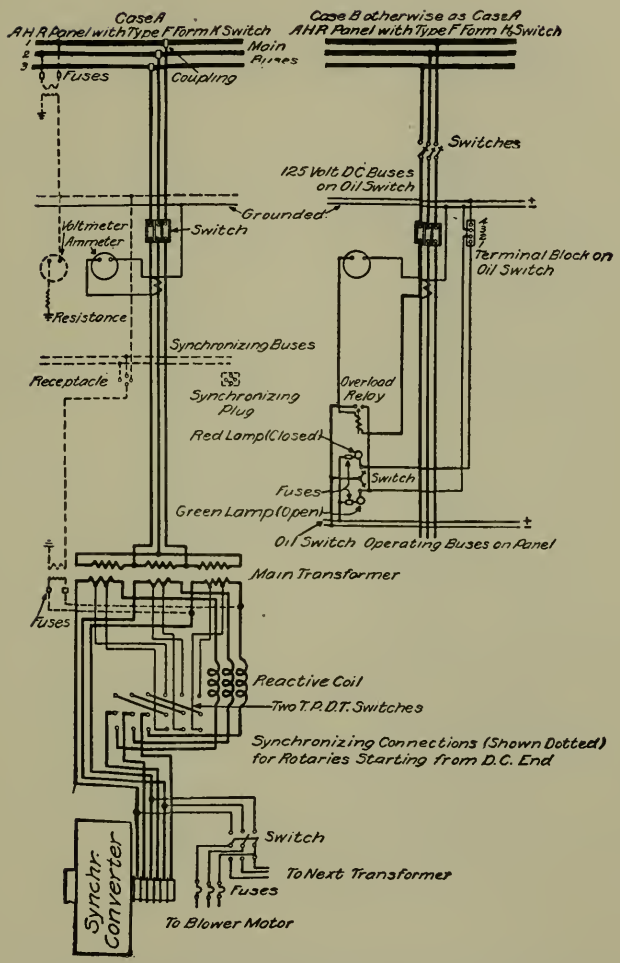


FIG. 108.—Connections for a six-phase synchronous converter and blower motor for air-blast transformers. Showing two methods of connection.

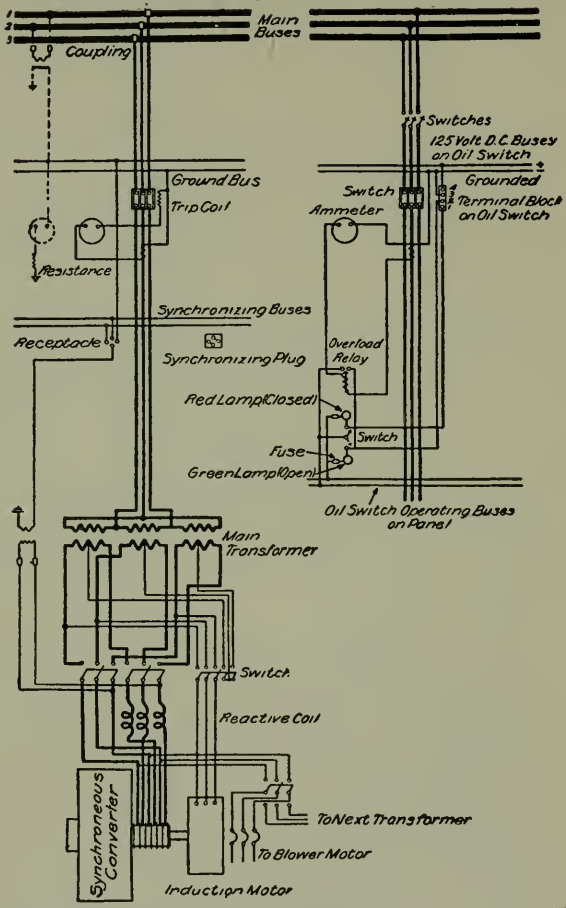


FIG. 109.—Connections of a six-phase converter with starting motor. Showing two methods of connection.

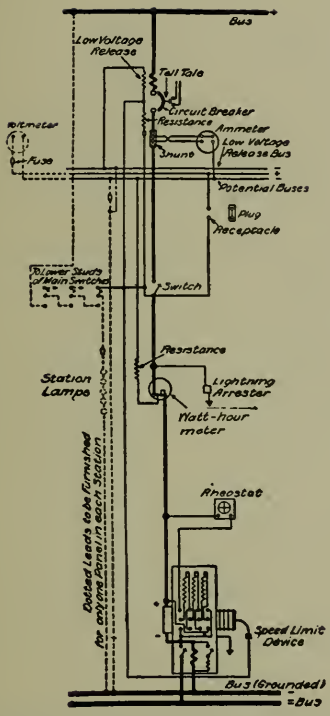


FIG. 110.—Connections of the direct-current side of a synchronous converter.

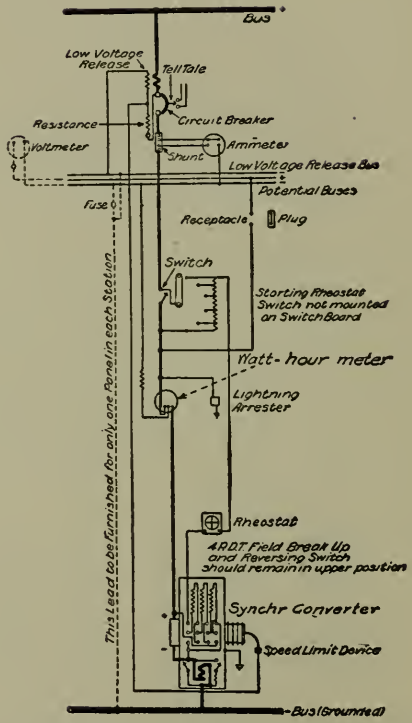


FIG. 111.—Connections of an inverted synchronous converter equipped with a speed-limiting device.

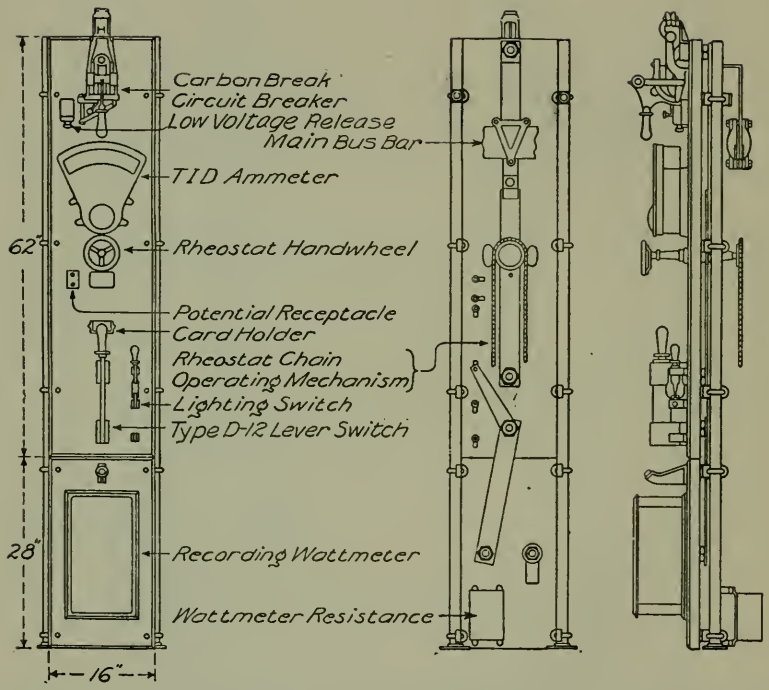


FIG. 112.—Panel for direct-current side of a synchronous converter for railway service. Rating: up to 1000 kw.

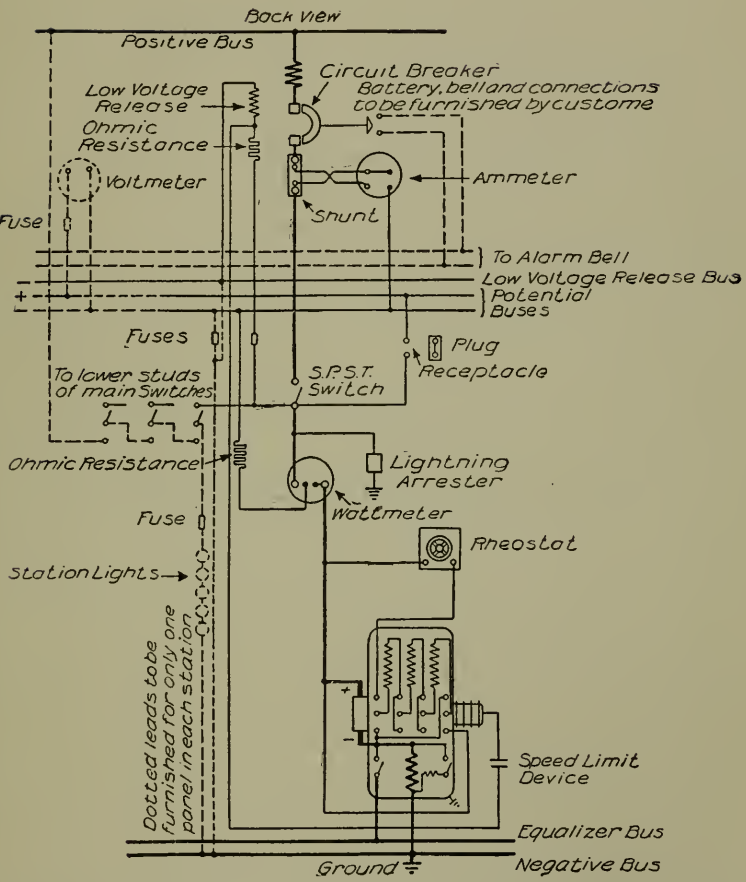


FIG. 113.—Connections for a synchronous converter panel shown in Fig. 112.

SECTION VII

BATTERIES AND BOOSTERS

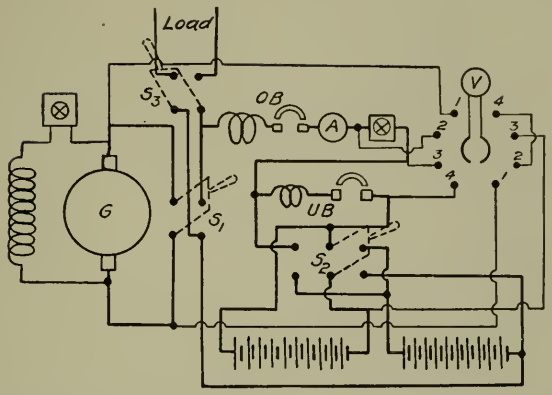


FIG. 114.—Connections for a small two-wire storage battery plant. B is an overload circuit breaker, and U B an underload circuit breaker. Switch S_2 is thrown to the right when charging the battery, and to the left when discharging it.

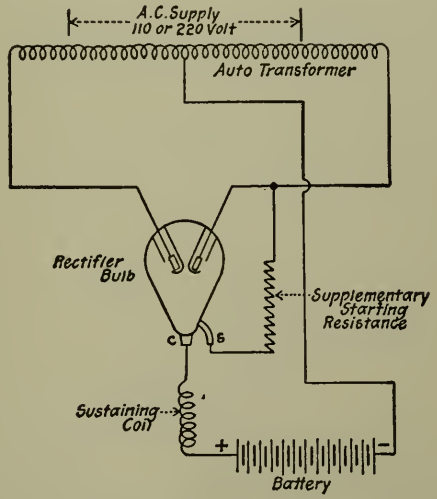


FIG. 115.—Connections of a mercury-vapor rectifier for charging a storage battery.

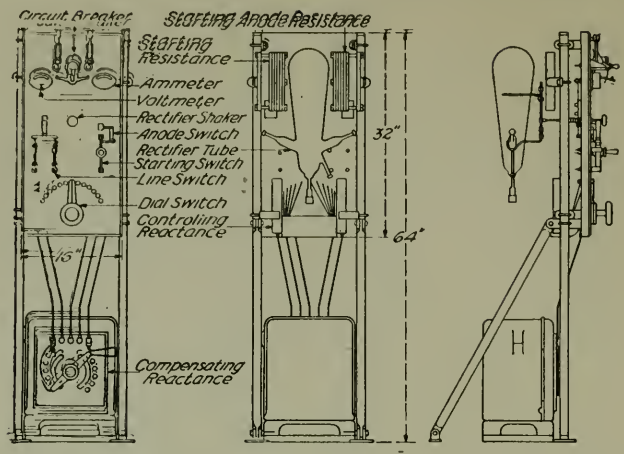
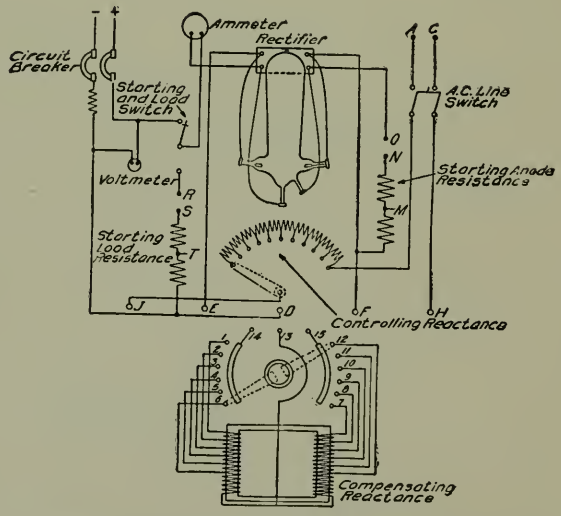


FIG. 116.—Mercury-arc rectifier panel for automobile battery charging system.



Connect E to 14, D to 13, F to 15

110 V. A.C. Line Voltage	For 15 to 30 Volts D.C.	Connect J to 1, H to 7, R to T and O to M
	" 30 - 45 " " "	J - 6, H - 12, R - S, - O - N
110-220 V.A.C. Line Voltage	Use 110 V.A.C. For 30 to 45 Volts D.C.	Connect J to 6, H to 12, R to 7, and O to N
	Use 220 V.A.C. " 40 - 75 " " "	J - 1, H - 7, R - S, - O - N
220 V.A.C. Line Voltage	For 45 to 75 Volts D.C.	Connect J to 1, H to 7, R to T and O to M
	" 75 - 115 " " "	J - 6, H - 12, R - S, - O - N
330 V.A.C. " "	For 90 to 120 Volts D.C.	Connect J to 1, H to 7, R to T, and O to M
	" 120 - 175 " " "	J - 6, H - 12, R - S, - O - N

FIG. 117.—Connections for the mercury-arc rectifier panel shown in Fig. 116.

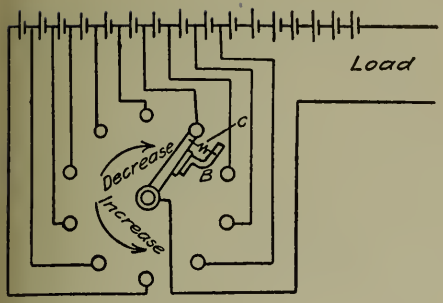


FIG. 118.

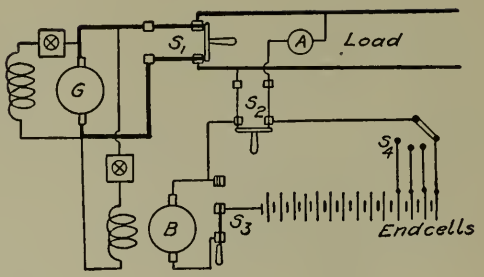


FIG. 119.

FIG. 118.—End-cell switch for a storage battery. B is an auxiliary contact connected to the main contact through a resistance C, but otherwise insulated from it. This auxiliary contact prevents the opening of the circuit, and the resistance C prevents the short-circuiting of the cell connected across adjacent point.

FIG. 119.—Connections for a shunt booster system. With switch S_2 down, the booster, B, assists the generator, G, to charge the battery. With it up, the battery is ready to discharge, the e.m.f. being regulated with an end-cell switch, S_4.

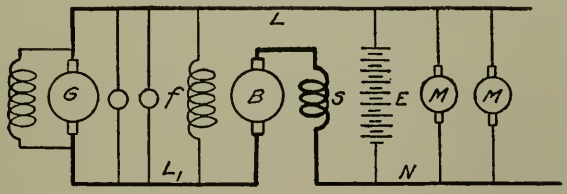


FIG. 120.—Connections for a non-reversible automatic booster system. The series field, S, opposes the generator, e.m.f. lamps are connected across the generator, where the e.m.f. remains constant, while the motors are connected across the battery, where the e.m.f. drops as the load comes on.

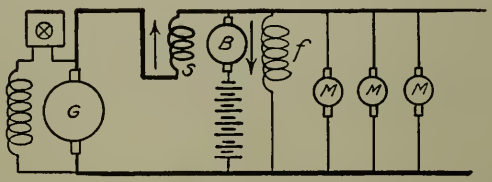


FIG. 121.—Connections for a reversible-automatic booster system. The series field, S, opposes the generator e.m.f.

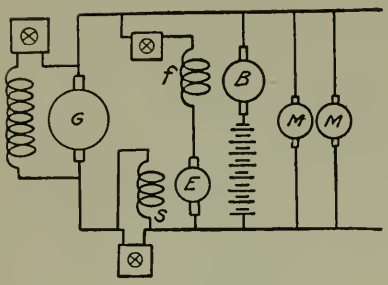


Fig. 122.

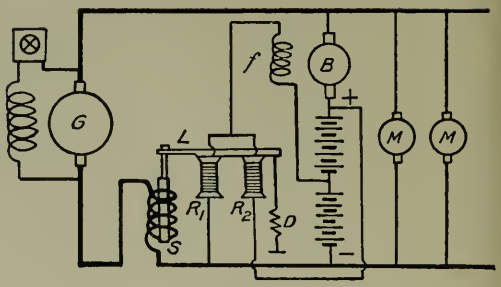


Fig. 123.

Fig. 122.—Connections for an externally controlled automatic booster system (Hubbard system). The series field, S, of the exciter, E, opposes the e.m.f. of the generator, G, and under normal conditions the exciter e.m.f. just neutralizes the generator e.m.f., and there is no current in the field winding, f. An increase in the generator current increases the exciter e.m.f. and produces e.m.f. in the booster, B, which assists the battery to discharge.

Fig. 123.—Connections for an externally controlled automatic booster system (Endt's system). L is a carbon-resistance regulator; S a solenoid, and D a spring. When the load is normal, the resistances, R_1 and R_2, are equal, and there is no current in the field winding, f. Any change in the value of the current through S will produce a change in the field strength of the booster, corresponding with the load both as to direction and intensity.

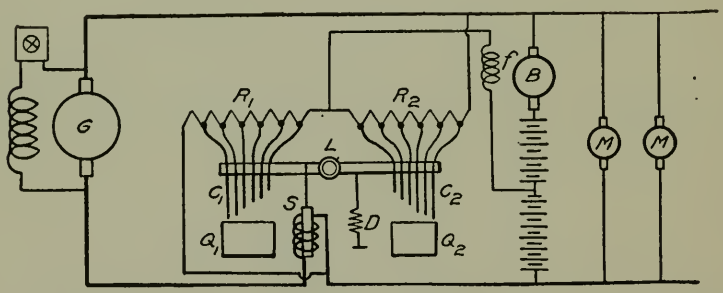


Fig. 124.—Connections for an externally controlled automatic booster system (Bijur). S is a solenoid; D a spring; C_1 and C_2 taps from a resister; Q and Q_2 vessels containing mercury. The magnet and spring are so designed that for a given current, the pulls of the magnet and the spring are the same, independent of the position of the lever, L; therefore, motion will continue until the current returns to its normal value and the maximum evaluation of the current is fixed by the pull necessary to overcome the friction of the moving parts.

SECTION VIII

SUB-STATIONS

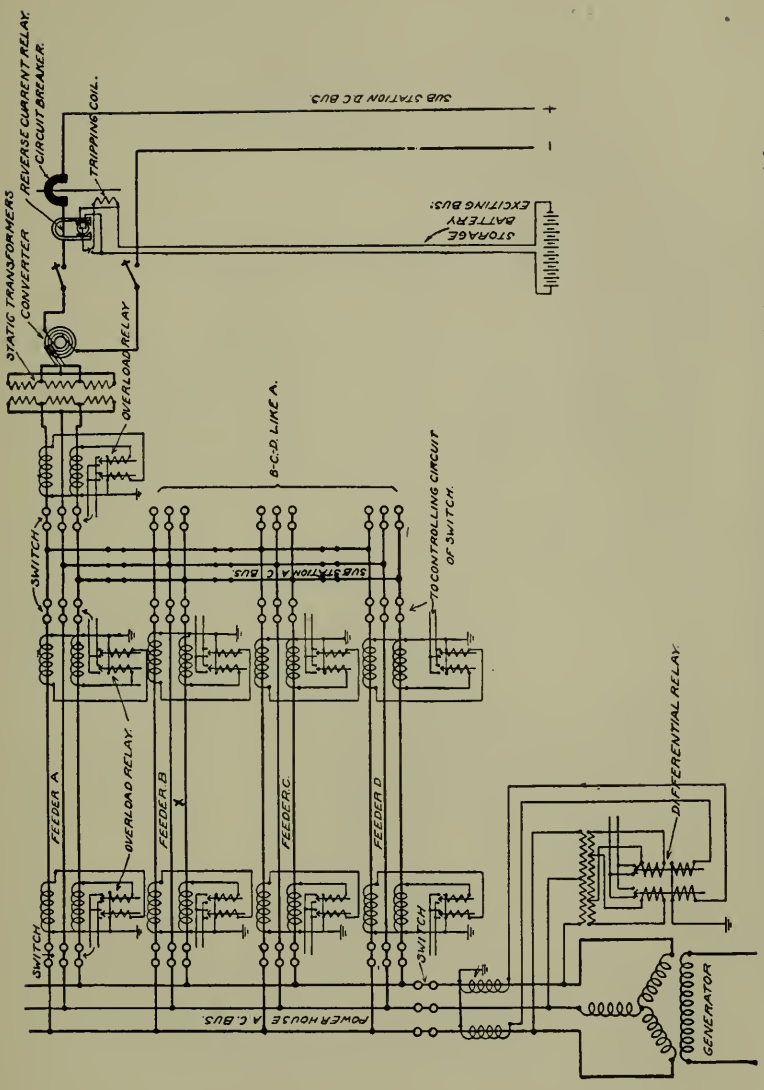


FIG. 125.—Connections of a three-phase generating and transmission system with a synchronous converter substation.

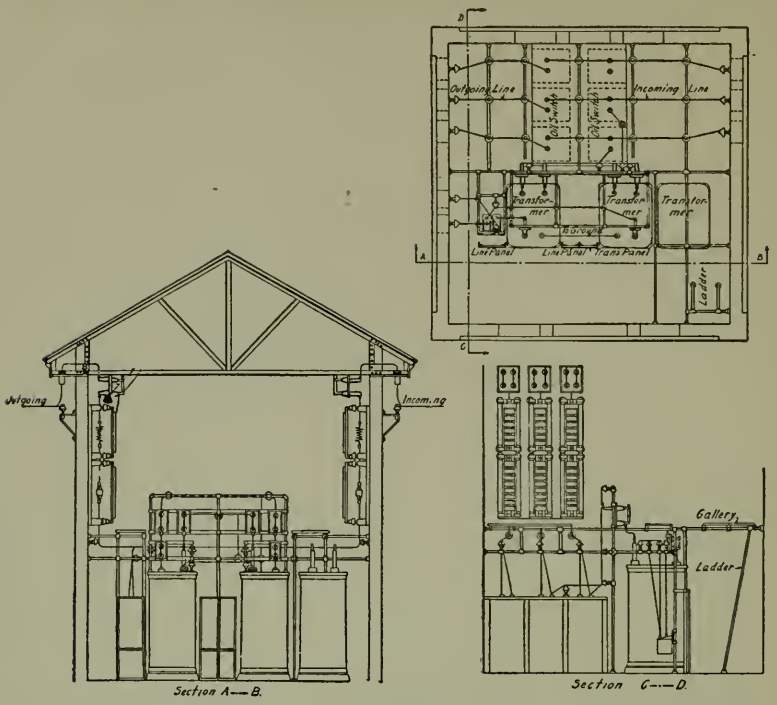


FIG. 126.—Transformer substation for single-phase 3300-volt railway distribution. Transmission line 3300 volts.

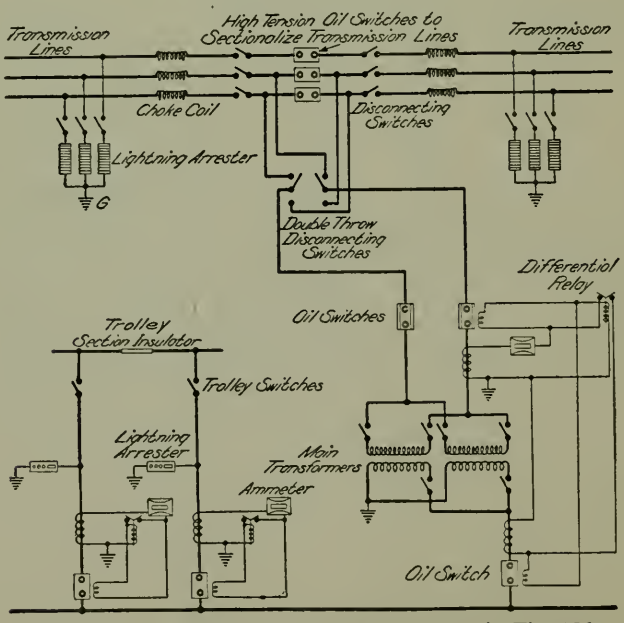


FIG. 127.—Connection for substation shown in Fig. 126.

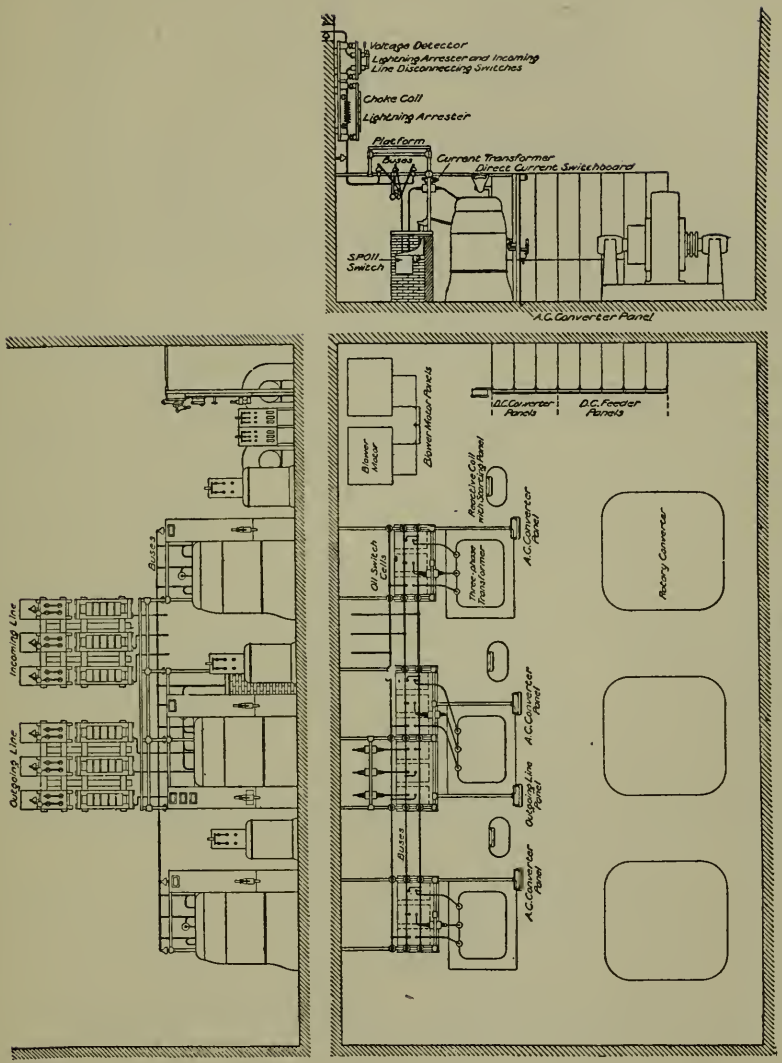


FIG. 128.—Section of a typical railway synchronous converter substation, using three-phase transformers. Transmission line 13,200 volts.

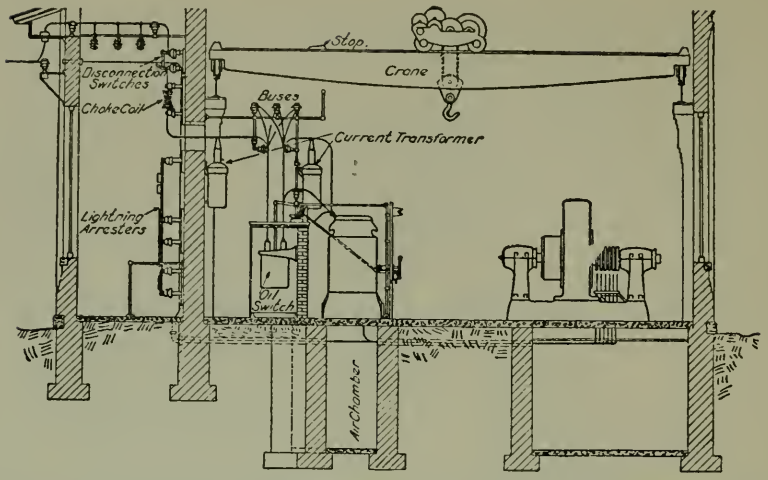


FIG. 129.—Longitudinal section through typical synchronous converter substation. 33,000-volt transmission line.

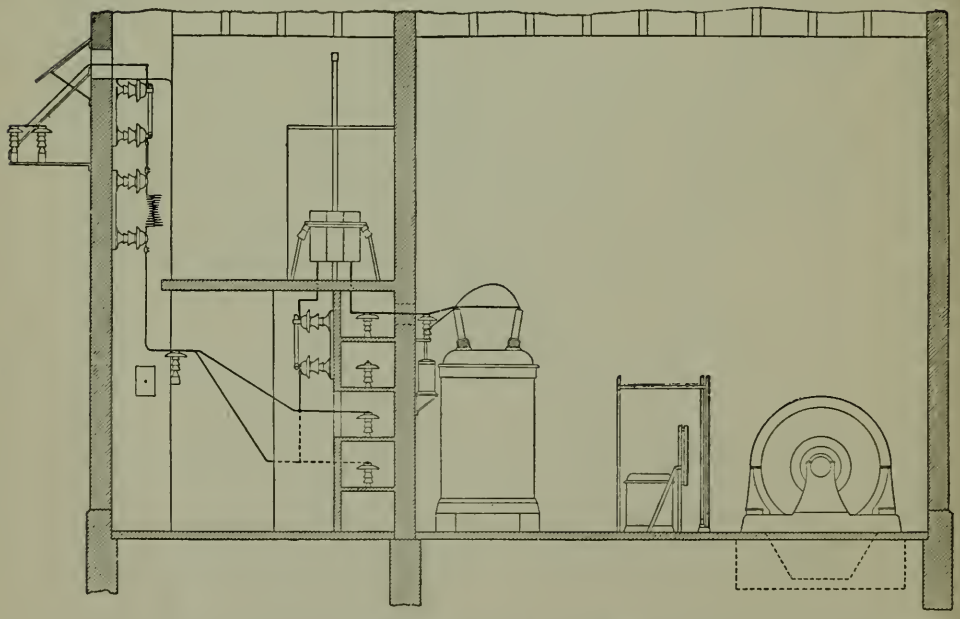


FIG. 130.—Section of typical synchronous converter substation (Oregon Electric Railway). 60,000-volt transmission line.

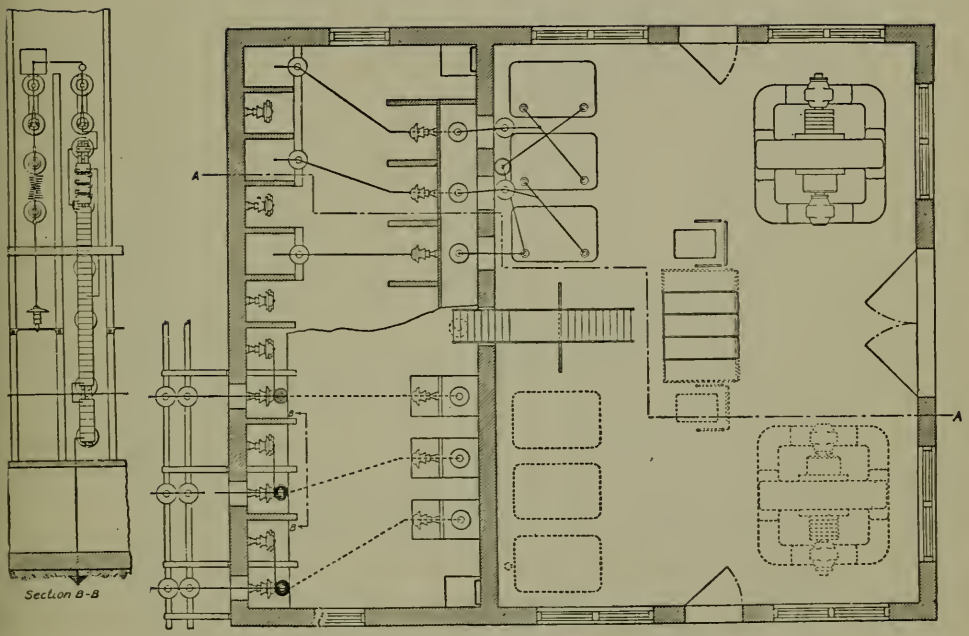


FIG. 131.—Plan of substation shown in Fig. 130.

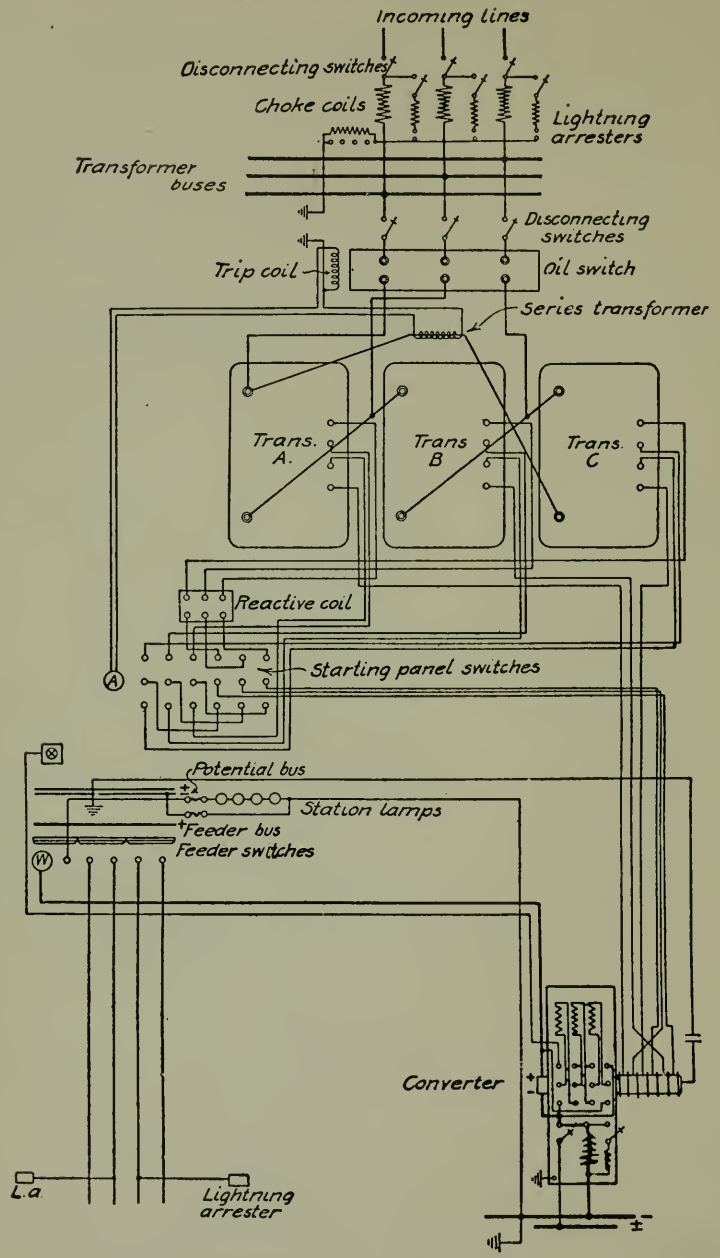


Fig. 132.—Wiring diagram of substation shown in Fig. 130.

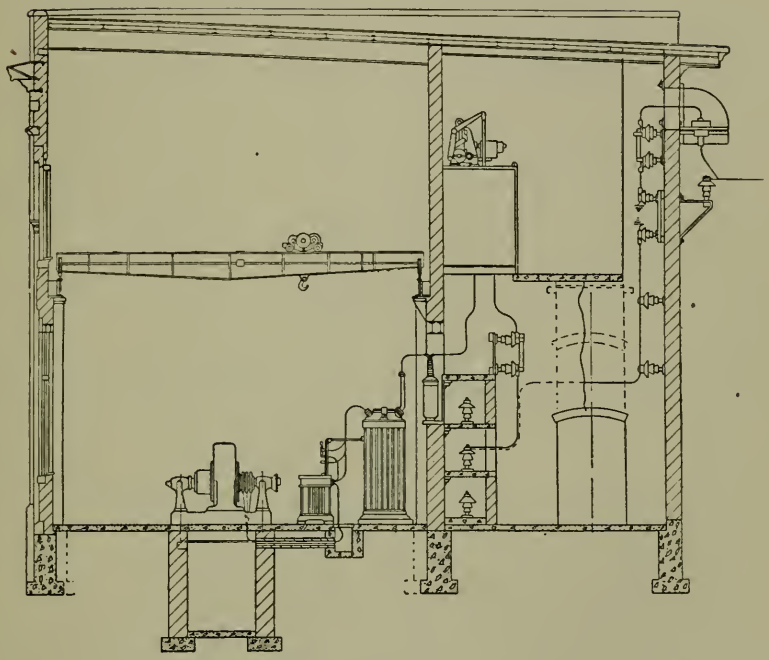


FIG. 133.—Typical synchronous converter substation (West Shore Railroad). 60,000-volt transmission line.

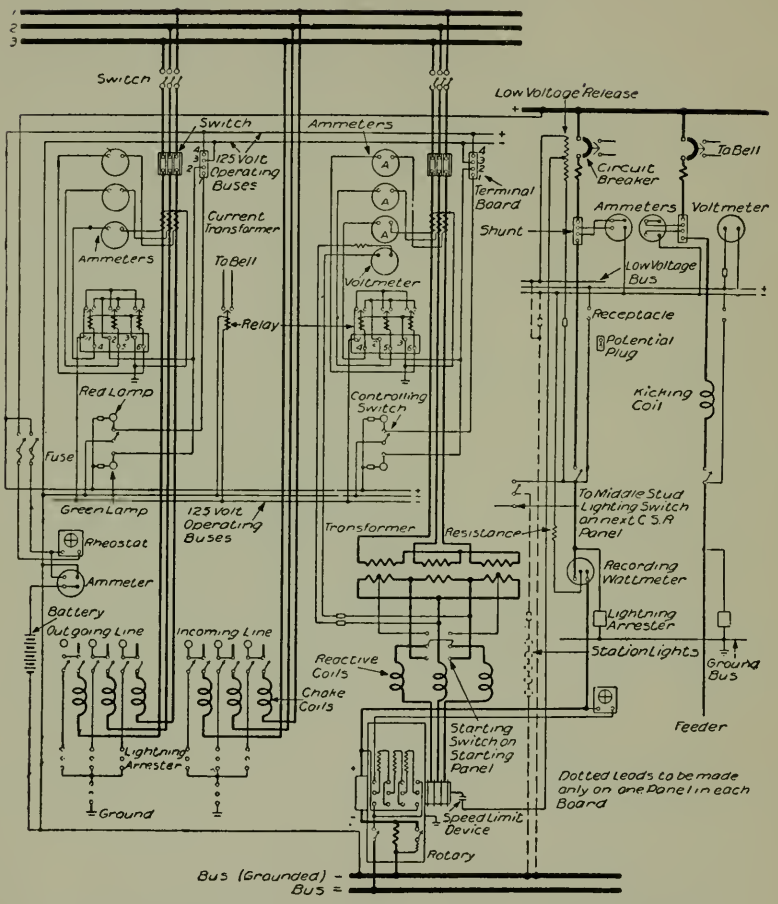


FIG. 134.—Connections for typical substation shown in Fig. 133.

SECTION IX

D. C. MOTORS AND SPEED CONTROL

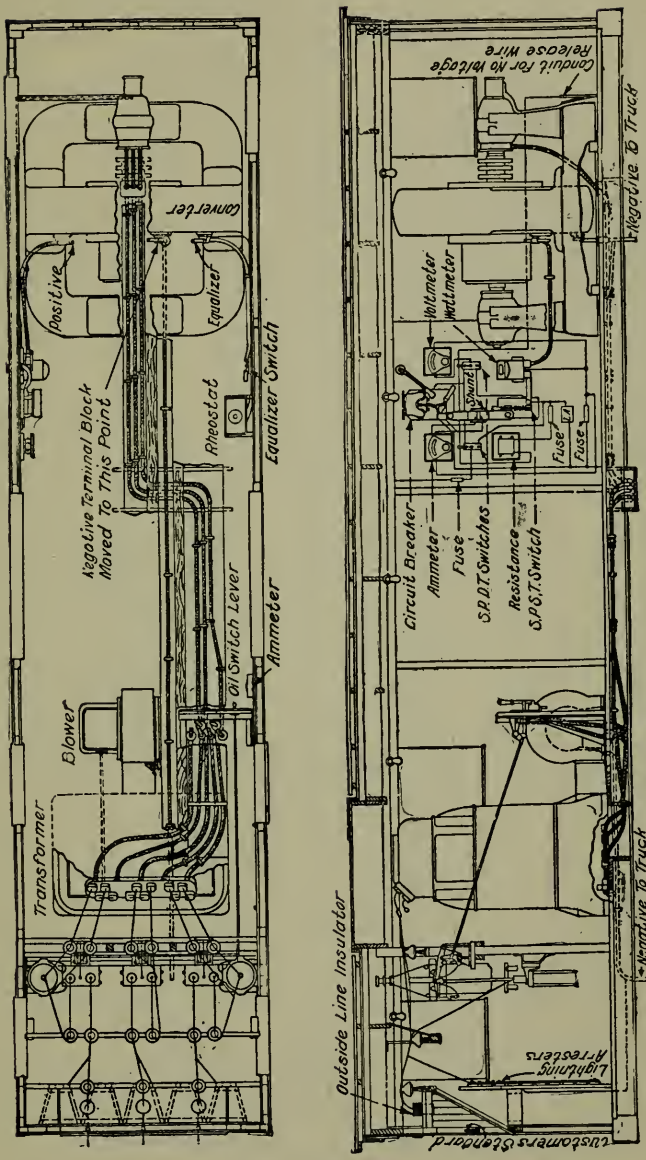


FIG. 135.—Portable railway substation. 400-kw. synchronous converter connected to a three-phase air-blast transformer. 33,000-volt primary.

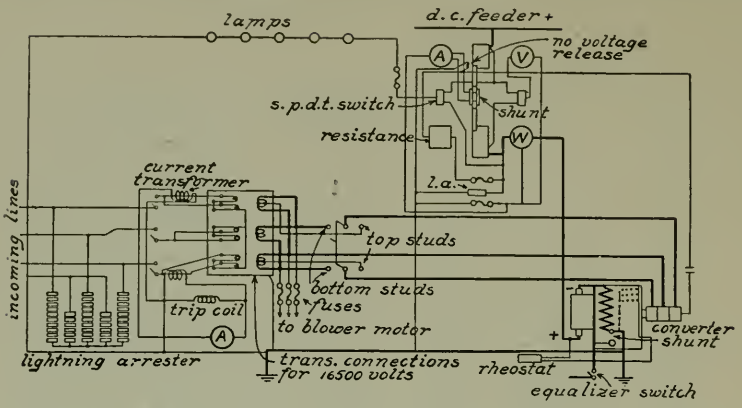


FIG. 136.—Wiring diagram for portable substation shown in Fig. 135.

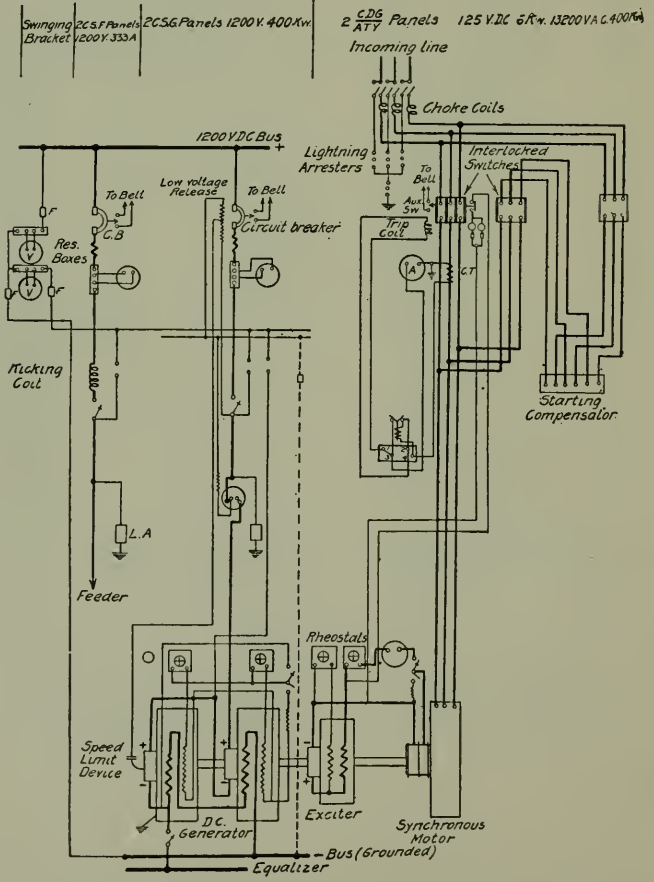


FIG. 137.—Connections for an a.c.–d.c. motor-generator substation.

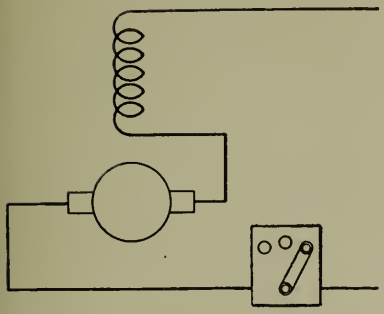


Fig. 138.—Plain series motor with starter. The speed varies with the load.

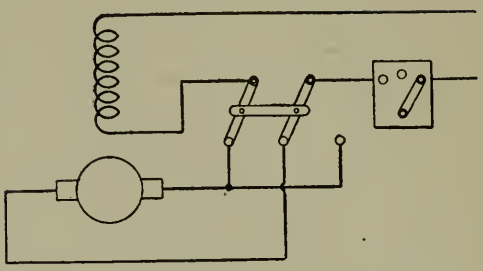


Fig. 139.—Reversing series motor with starter.

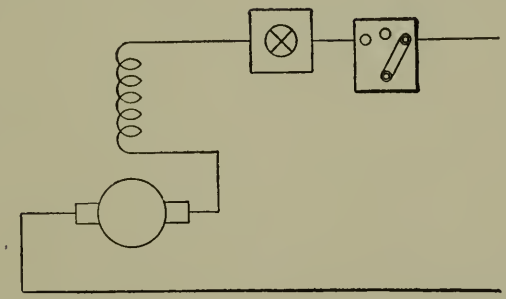


Fig. 140.—Series motor. Speed regulation by inserting resistance in series. Increase in resistance decreases the speed.

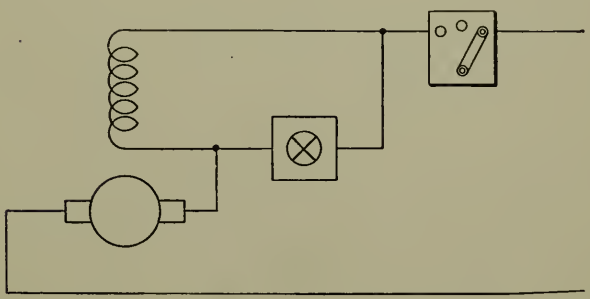


Fig. 141.—Series motor. Speed regulated by inserting resistances in shunt with the field winding. Decrease in resistance increases the speed.

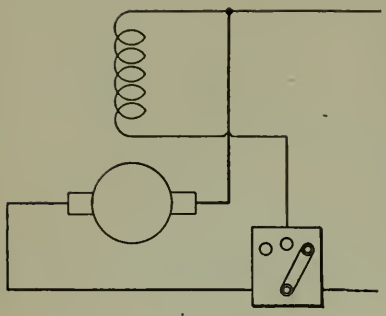


FIG. 142.—Plain shunt motor with starter. Speed practically constant, drops slowly with heavy load.

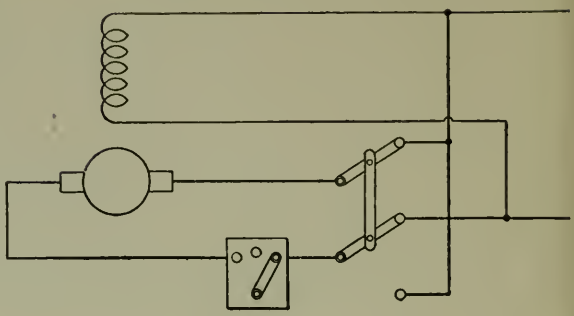


FIG. 143.—Reversing shunt motor with starter.

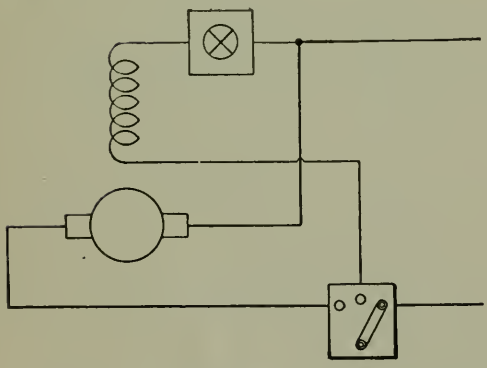


FIG. 144.

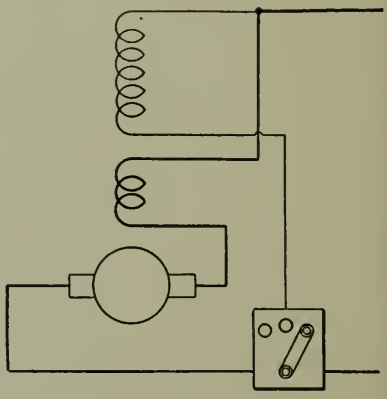


FIG. 145.

FIG. 144.—Shunt motor. Speed regulated by inserting resistance in series with the field winding. Increase in resistance increases speed.

FIG. 145.—Plain compound motor. Speed characteristics depend upon design. Series coil tends to decrease speed with load when connected to assist the shunt winding, and when connected in opposition tends to increase the speed with the load. When used to increase the speed it is called a "differential winding."

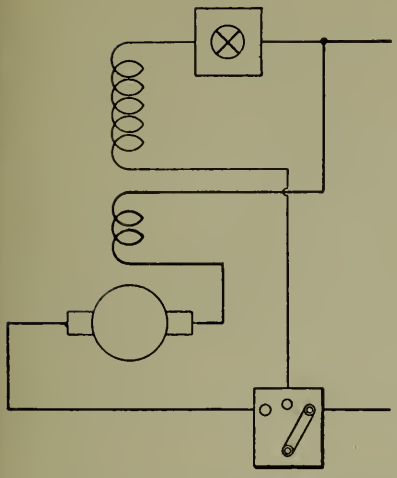


FIG. 146.—Compound motor with rheostat and field circuit for field regulation.

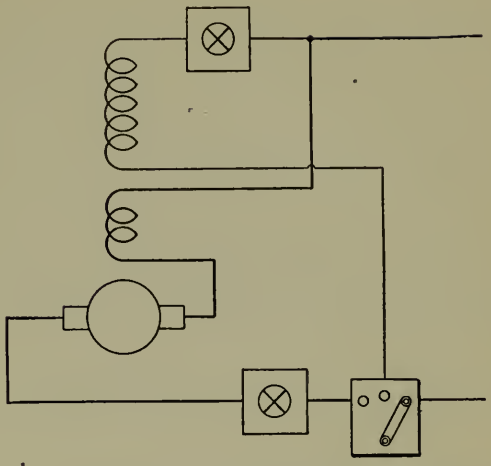


FIG. 147.—Compound motor with rheostats in both field and armature circuits for speed regulation.

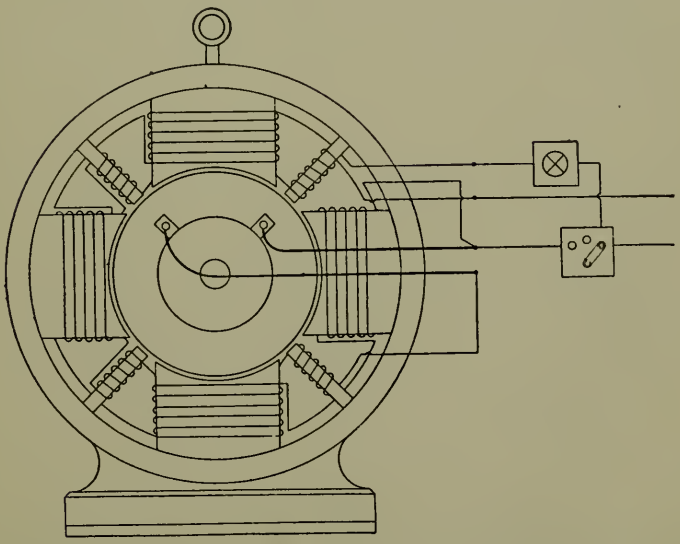


FIG. 148.—Inter-pole shunt motor. Speed adjusted by resistance in shunt field circuit. Speed can be varied over a large range without sparking and at constant output.

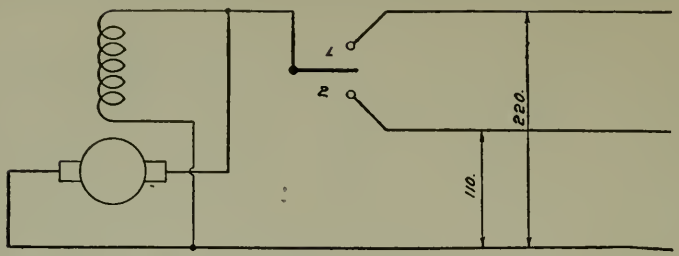


FIG. 149.—Multiple voltage speed control. Switch connected to 1 gives the speed corresponding to 220 volts, and connected to 2, that corresponding to 110 volts. The field strength remaining constant, the speed is directly proportional to the voltage across the armature.

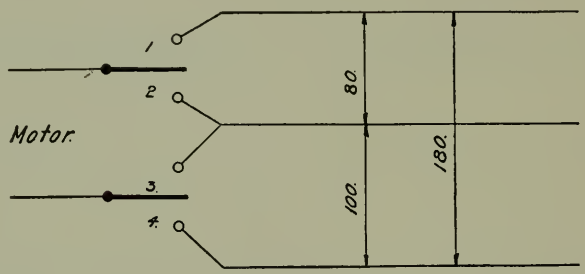


FIG. 150.—Multiple voltage speed control. Three speeds:

Switches	Speed in per cent.
1–3	1.
2–4	1.25
1–4	2.25

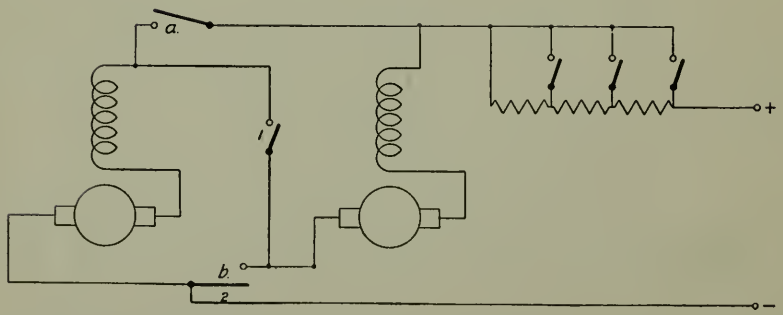
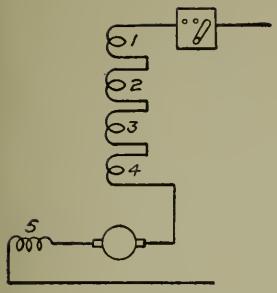


FIG. 151.—Series-parallel speed control. Switch 1 closed; motors in series; speed-1; switches a and b closed; 1 open; motors in parallel; speed-2.



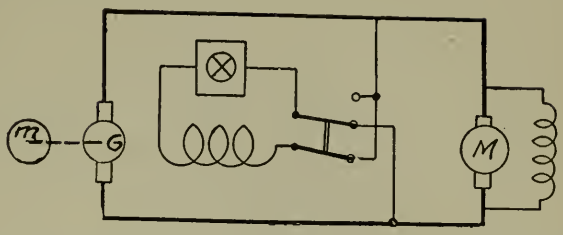


Fig. 152. Fig. 153.

Fig. 152.—Compensated series motor with four series coils which can be connected in series or parallel according to the series-parallel method of control. The compensating winding prevents sparking.

Fig. 153.—Motor-generator speed control. The motor, m, may be of any type, gas or electric (a.c. or d.c.). The speed of M, the working motor, is controlled by varying the field of the generator, G.

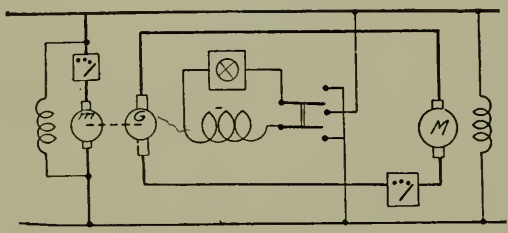


Fig. 154.—Ward Leonard motor-generator speed control. The speed is controlled by regulating the field strength of the generator, G. The motor is reversed by reversing the field of the generator. All power must be supplied from the line through motor m.

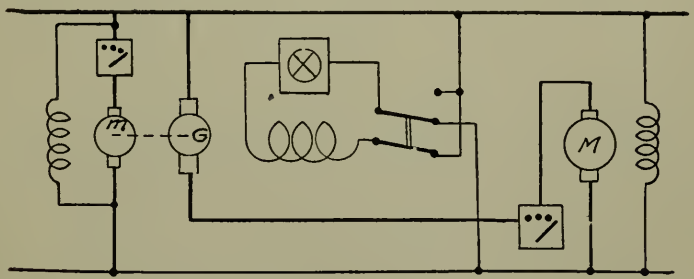


Fig. 155.—Ward Leonard boost and retard speed control system. The voltage of the generator, G, is either added to or subtracted from that of the line by adjusting the field. Speed controlled by adjusting field strength of G. Only part of the power is supplied from motor m. To obtain speeds below normal, G runs as a motor, m becomes a generator, and returns to the power of the line.

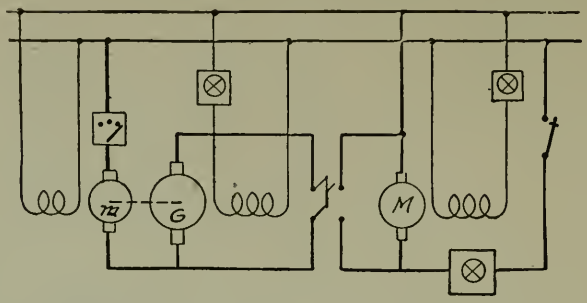


FIG. 156.—Teaser system of speed control (Bullock). The generator of the motor-generator set is wound for low voltage and large current so that in starting it can supply full load current at such a low voltage that no starting rheostat is needed, and the desired torque can be developed since it depends only upon the value of the current and the field flux. By increasing the voltage the motor can be speeded up until it can be thrown directly on the line and the teaser cut out. This arrangement is suitable for motors called on to operate at speeds much below normal, as in printing press drives.

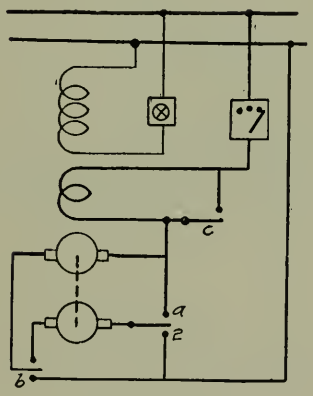


FIG. 157.

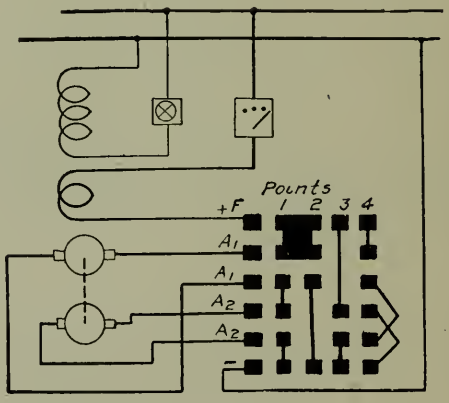


FIG. 158.

FIG. 157.—Double armature control (General Electric). Two similar windings on the same armature with a commutator on each end. Field the same as any ordinary motor (shunt or compound). With switches 1 and 2 closed, the armatures are in series and run at half speed. With switches a and b closed, the armatures are in parallel and run at full speed. These two normal speeds can be varied somewhat by varying the shunt field and cutting out the series field with switch c.

FIG. 158.—Double armature speed control (C & C). Two windings on one armature with a commutator on each end. The field is the same as any other motor (shunt or compound). The armature has $2x$ turns in series, and the other has $3x$; so that the normal speed of the armatures are to each other as 3 is to 2; that is, inversely as the number of the turns. If the windings are connected in series (first point of the controller) $5x$ turns are effective and the speed is a minimum; when connected in opposition, $3x-2x=x$ turns are effective and the speed is a maximum. Two intermediate running speeds are obtained by using each armature alone, and slight variations from any one of the four running speeds are obtained by resistance in the field circuit or in series with the armature.

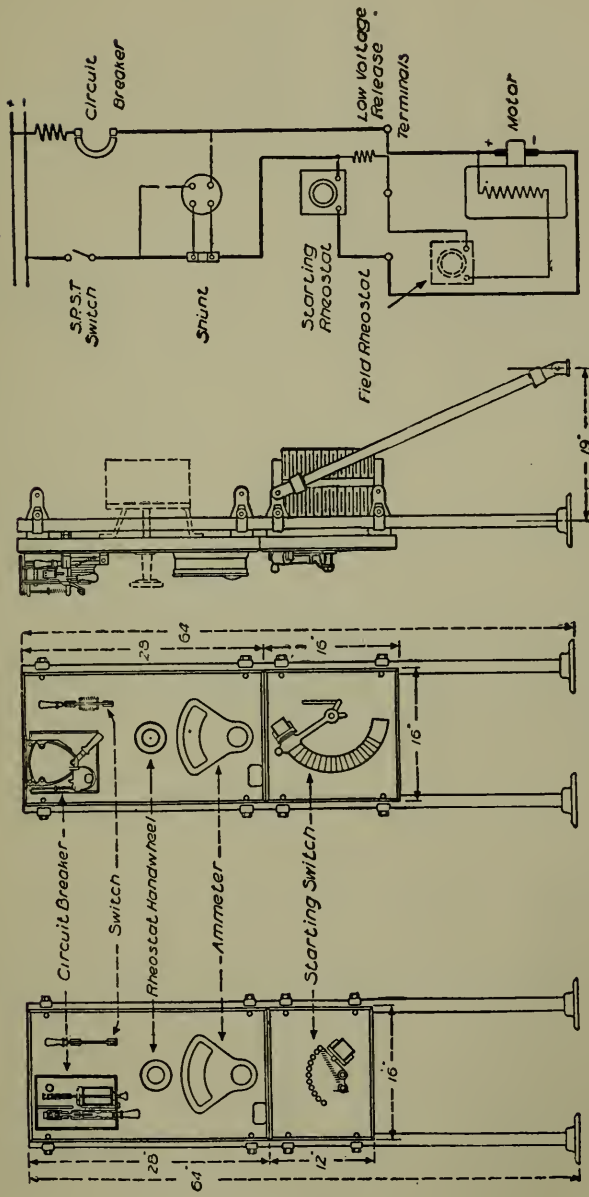


FIG. 159.—Starting panel for direct-current shunt motor.

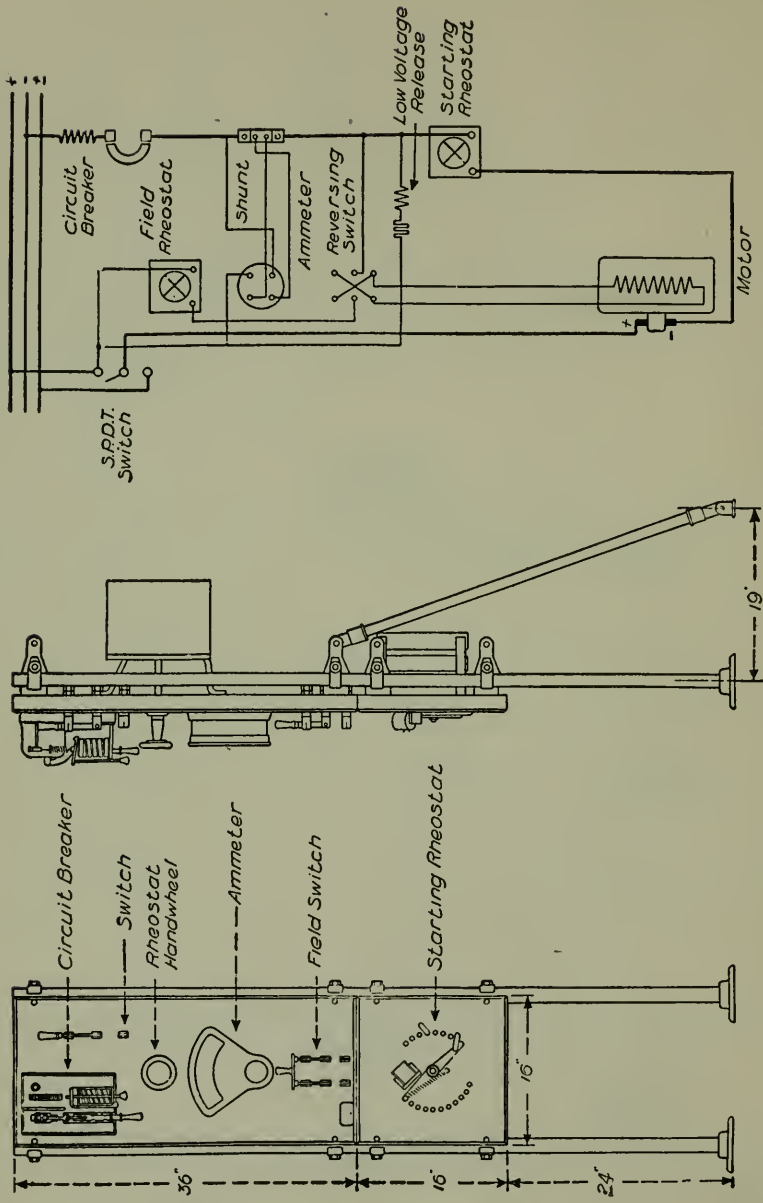


FIG. 160.—Starting panel for d.c. reversing shunt motor.

SECTION X

A. C. MOTORS AND SPEED CONTROL

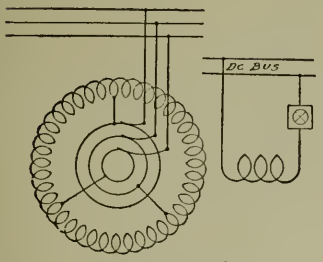


FIG. 161.—Three-phase synchronous motor. Stationary field.

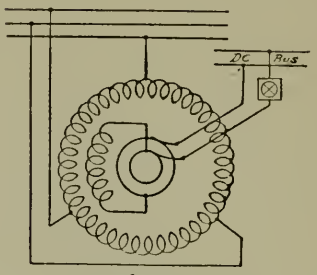


FIG. 162.—Three-phase synchronous motor. Revolving field.

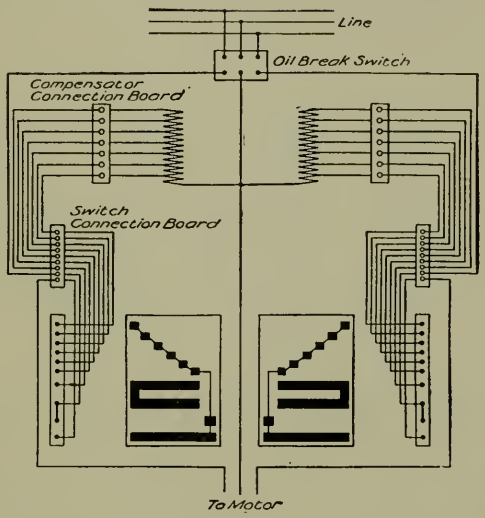


FIG. 163.—Connections of an auto-transformer used for starting a three-phase synchronous motor.

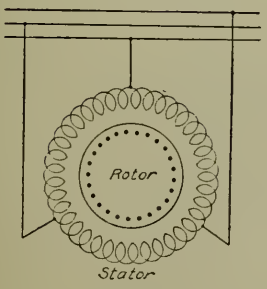


FIG. 164.

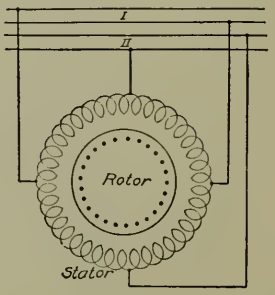


FIG. 165.

FIG. 164.—Three-phase induction motor. Squirrel-cage secondary. When running at full speed one lead can be disconnected and the motor will continue to operate single-phase.

FIG. 165.—Two-phase induction motor. Squirrel-cage secondary. When running at full speed one phase can be disconnected and the motor will continue to operate on the other phase.

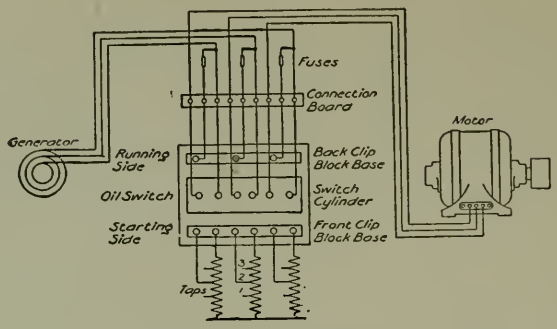


FIG. 166.—Connections of self-contained auto-starter for three-phase induction motor with squirrel-cage secondary. Rating: 300 amp. per phase up to 500 volts.

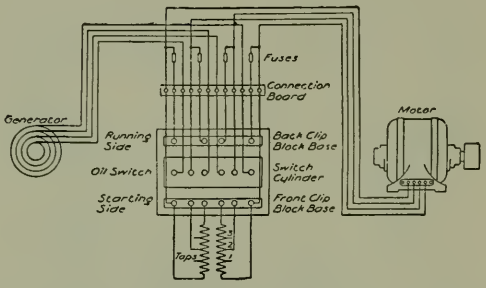


FIG. 167.—Connections of self-contained auto-starter for two-phase induction motor with squirrel-cage secondary. Rating: 300 amp. per phase up to 550 volts.

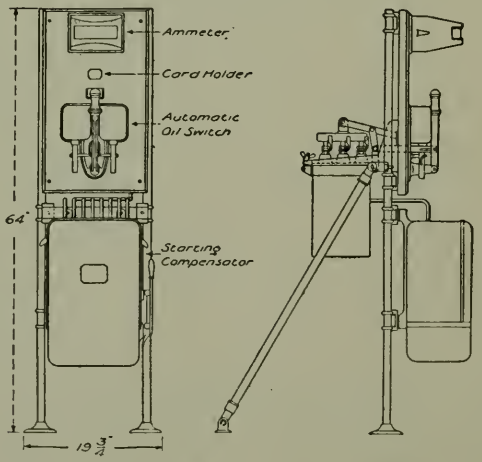


FIG. 168.—Polyphase induction motor. Starting panel.

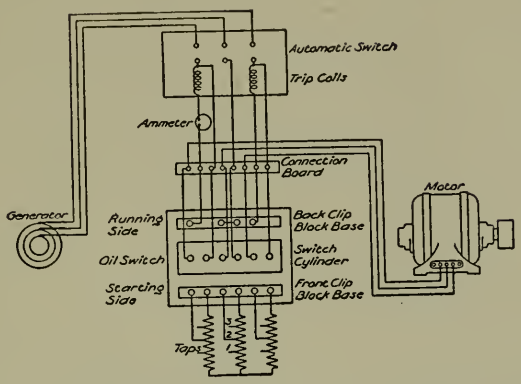


Fig. 169.—Connections for the auto-starter panel shown in Fig. 167 when used with three-phase motor. Rating: 100 amp. per phase, from 1000 to 2500 volts.

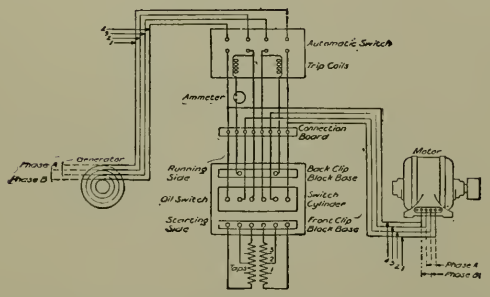


Fig. 170.—Connections for the auto-starter panel shown in Fig. 167 when used with two-phase motor. Rating: 100 amp. per phase, from 1000 to 2500 volts.

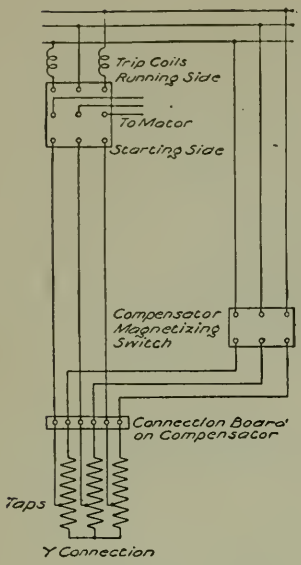


FIG. 171.

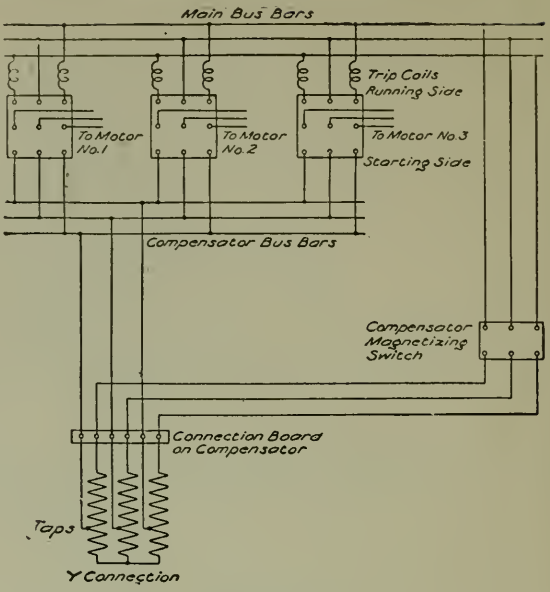


FIG. 172.

FIG. 171.—Connections for starting three-phase induction motor where the starting switch is external to the auto-transformer case. Rating: 300 amp. per phase up to 550 volts, 100 amp. per phase above 2500 volts.

FIG. 172.—Connections for starting any number of three-phase induction motors with one auto-transformer. Motors must be started in succession and when all are running the magnetizing switch is opened. Rating: 300 amp. per phase up to 550 volts, and 100 amp. per phase above 2500 volts.

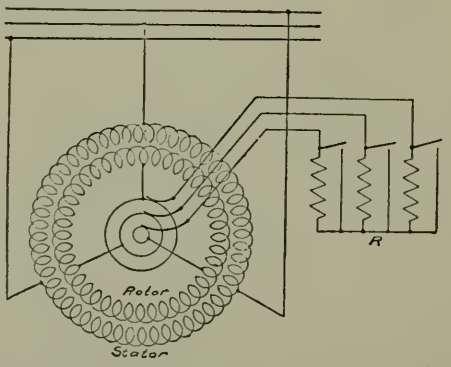


FIG. 173.—Three-phase induction motor with wound secondary. The resistance, R, connected across the slip rings may be internal or external. It is left in circuit until the motor has come up to speed, when it is short-circuited. When external to the motor, it is sometimes used to regulate the speed, although it is a very inefficient method of speed regulation.

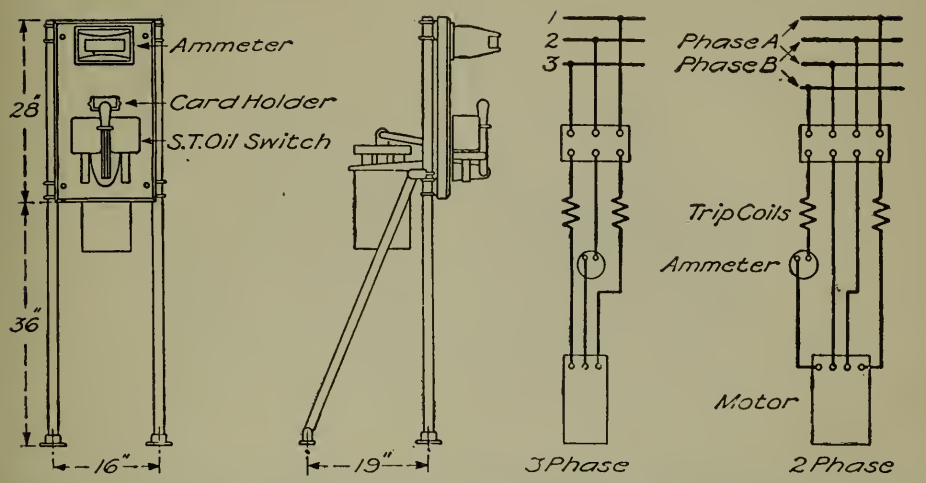


FIG. 174.—Starting and control panel for three-phase induction motor with wound secondary and internal starting resistance.

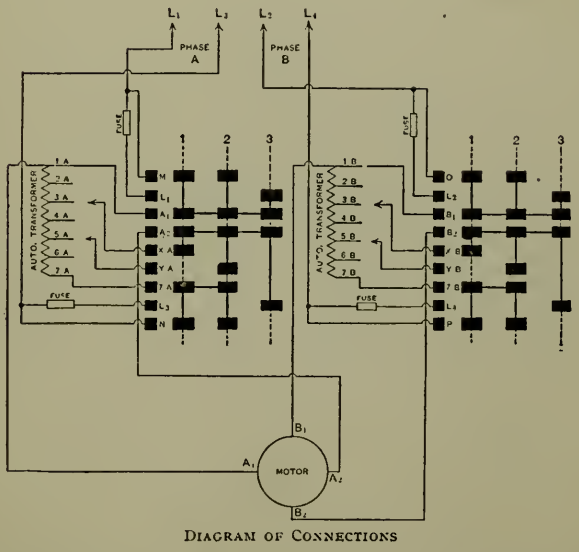


FIG. 175.—Connections for three-point auto-starter for a two-phase induction motor.

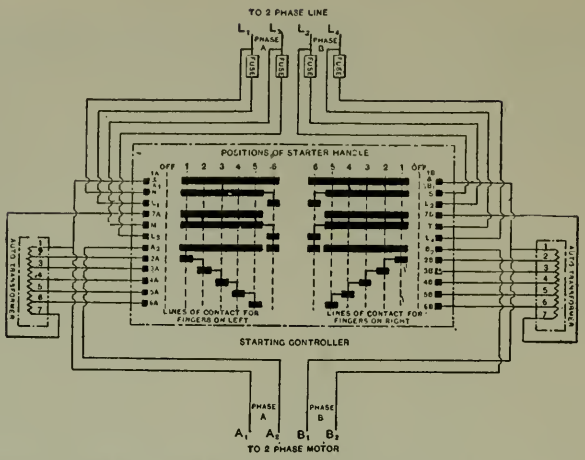

TO 2 PHASE LINE
PHASE A
PHASE B
FUSES
POSITIONS OF STARTER HANDLE
OFF 1 2 3 4 5 6 6 5 4 3 2 1 OFF
LINES OF CONTACT FOR FINGERS ON LEFT
LINES OF CONTACT FOR FINGERS ON RIGHT
AUTO TRANSFORMER
STARTING CONTROLLER
PHASE A
PHASE B
TO 2 PHASE MOTOR

FIG. 176.—Connections of a six-point auto-starter with a two-phase induction motor, 500 volts.

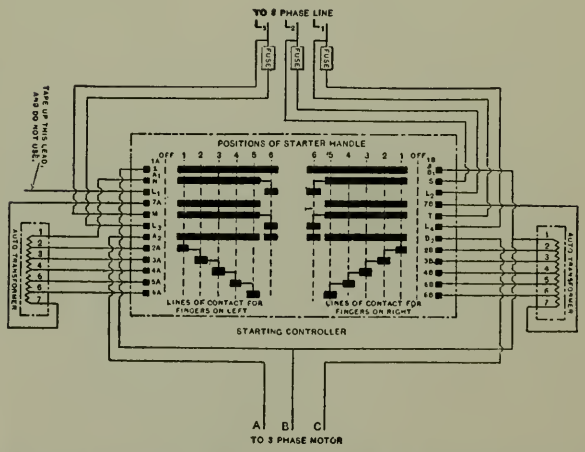

TO 3 PHASE LINE
FUSES
TAPE UP THIS LEAD, AND DO NOT USE.
POSITIONS OF STARTER HANDLE
OFF 1 2 3 4 5 6 6 5 4 3 2 1 OFF
LINES OF CONTACT FOR FINGERS ON LEFT
LINES OF CONTACT FOR FINGERS ON RIGHT
AUTO TRANSFORMER
STARTING CONTROLLER
A B C
TO 3 PHASE MOTOR

FIG. 177.—Connections of a six-point auto-starter for a three-phase induction motor, 100 volts.

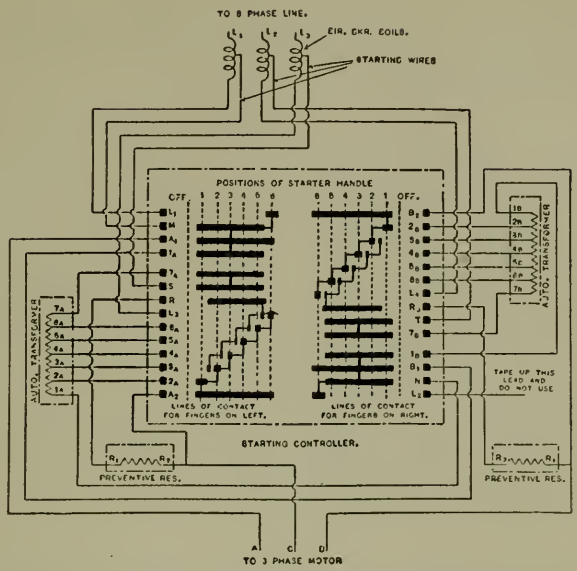


FIG. 178.—Connections of a six-point auto-starter for a three-phase induction motor, 1000 to 6000 volts.

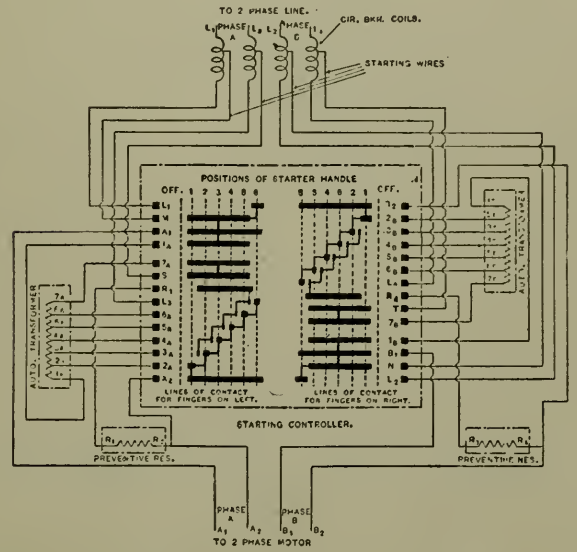


FIG. 179.—Connections of a six-point auto-starter for two-phase induction motor, 1000 to 2000 volts.

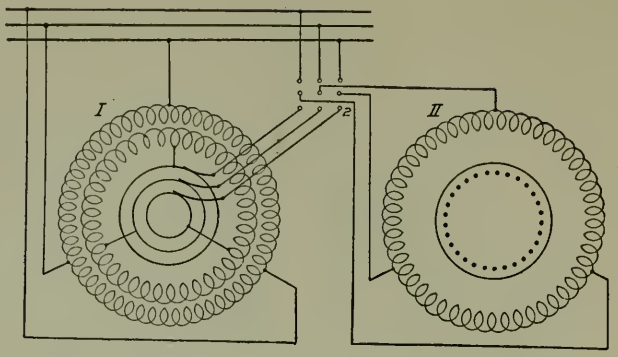


FIG. 180.—Two induction motors connected in tandem or concatenation. The primary motor must have a wound secondary. The second motor may have either a wound secondary or a squirrel-cage secondary. Both motors are mounted on the same shaft. When connected in parallel across the line, the motors run at full speed, and when connected in concatenation, they run at half speed, thus giving two running speeds.

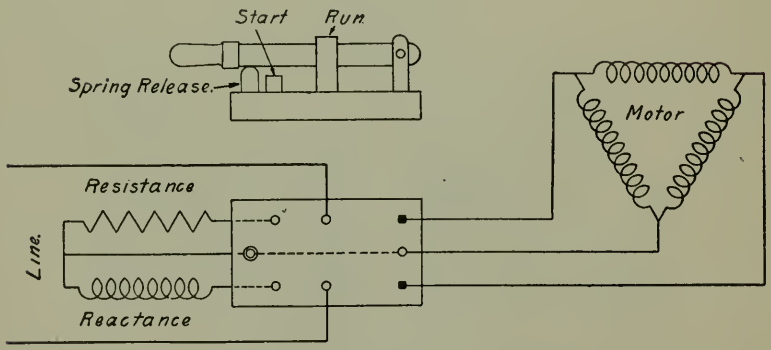


FIG. 181.—Connections for starting single-phase induction motor with three-phase winding, ratings below one horsepower. When starting, throw the switch and press it against the starting contacts until full speed is attained, then release the starting handle, which will be pushed up by the release spring, disconnecting the starting resistance and reactance.

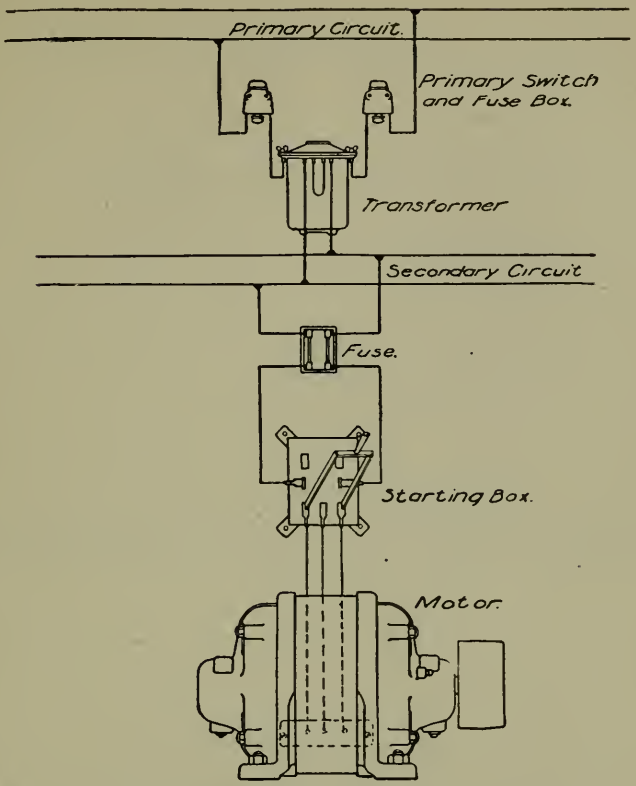


FIG. 182.—Arrangement of apparatus for starting split-phase motor shown in Fig. 181.

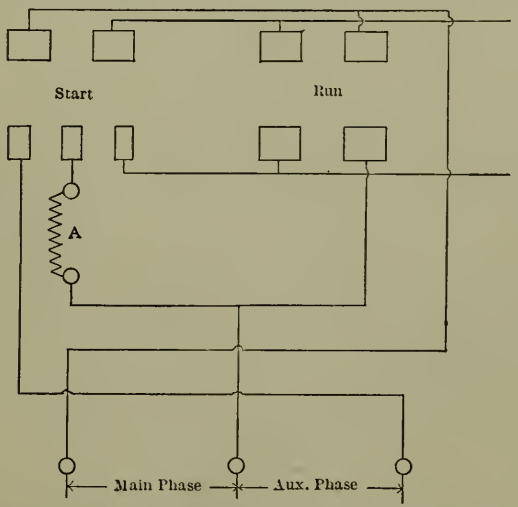


FIG. 183.—Connections of starting switch for single-phase induction motor with two-phase winding. Resistance, A, is connected across one phase when starting.

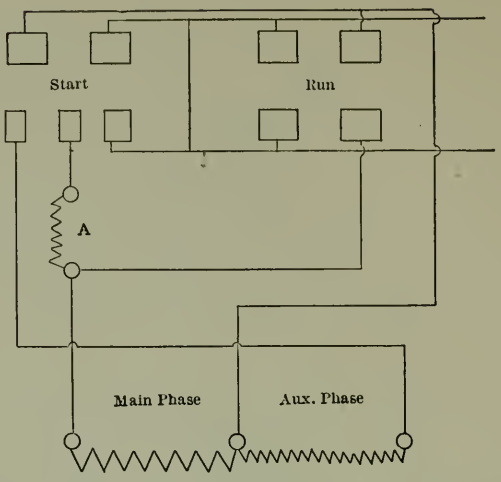


FIG. 184.—Connections of starting switch for single-phase induction motor with two-phase winding. Resistance, A, is connected in series when starting.

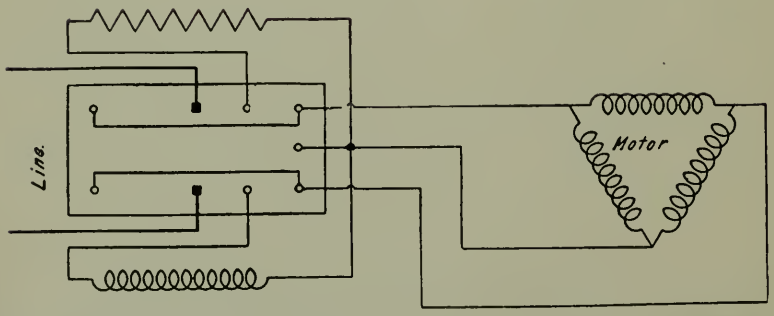


FIG. 185.—Connections for starting single-phase induction motor with three-phase winding.

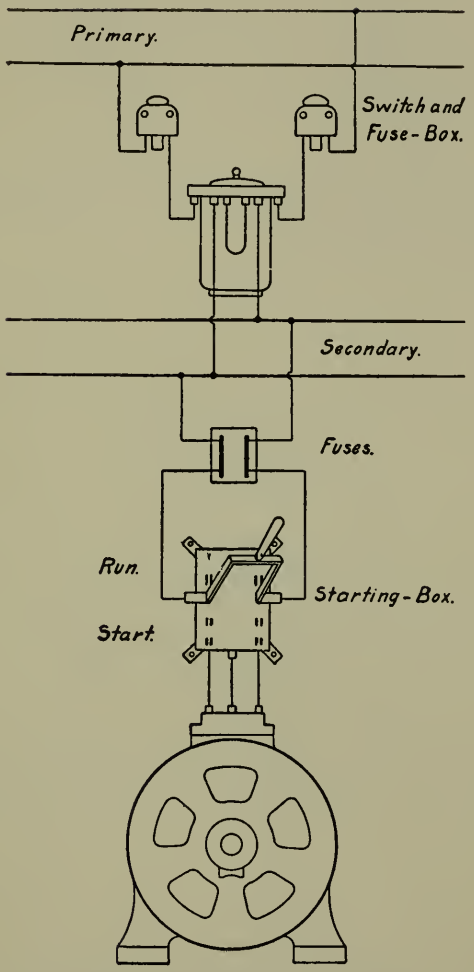


FIG. 186.—Arrangement of apparatus for starting split-phase motor shown in Fig. 185.

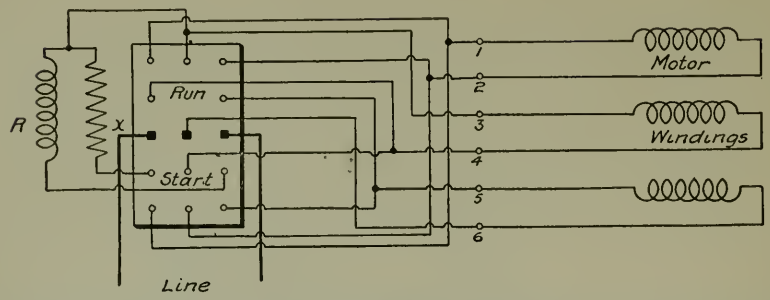


FIG. 187.—Connections for starting single-phase induction motor with three-phase winding. The phases are independent and arranged so as to be connected in star when starting, and in delta when running.

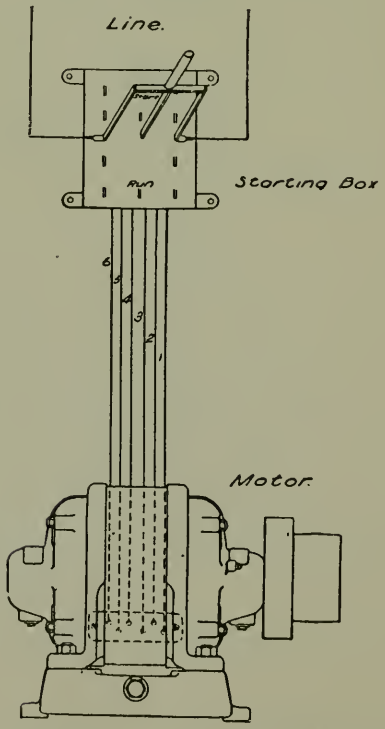


FIG. 188.—Arrangement of apparatus for starting split-phase motor shown in Fig. 187.

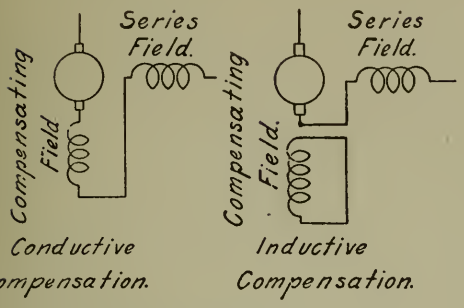


FIG. 189.—Single-phase series motor with compensated armature.

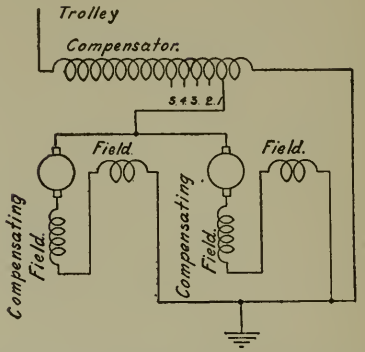


FIG. 190.—Tap method of control for single-phase series motors. The voltage across the motors is varied by connecting to taps brought out from an auto-transformer.

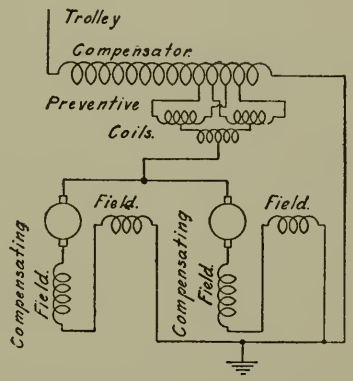


FIG. 191.—Tap control of single-phase series motors, using preventive coils. The preventive coils eliminate sparking at the transformer taps and prevent the short-circuiting of leads included between two adjacent taps. The operation of these coils is explained in the section on railway equipment, see Fig. 385.

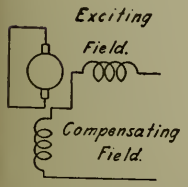


FIG. 192.—Compensated single-phase repulsion motor.

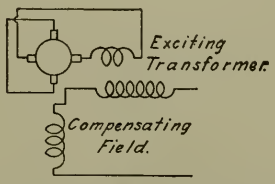


FIG. 193.—Winter-Eichberg single-phase motor.

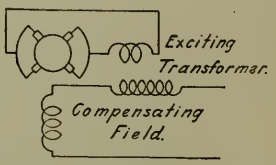
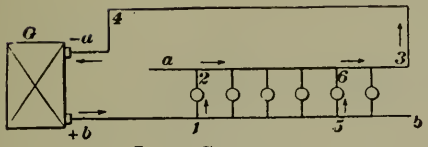


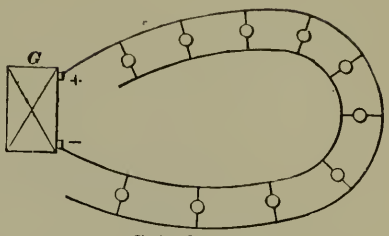
FIG. 194.—Latour single-phase motor.

SECTION XI

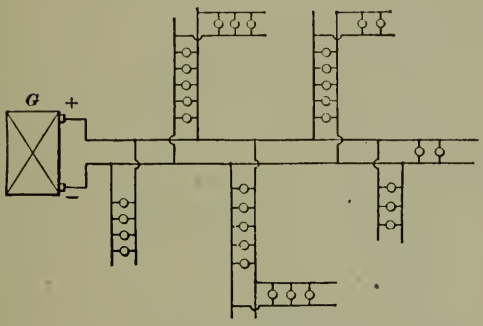
CONSTANT POTENTIAL DISTRIBUTION



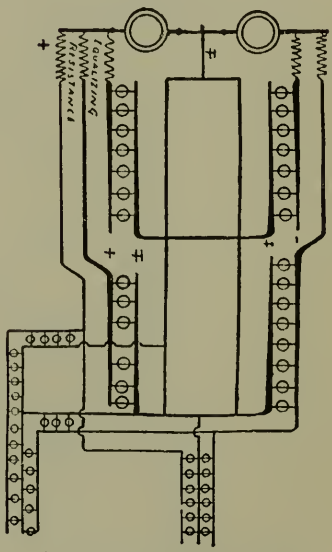
Loop System.



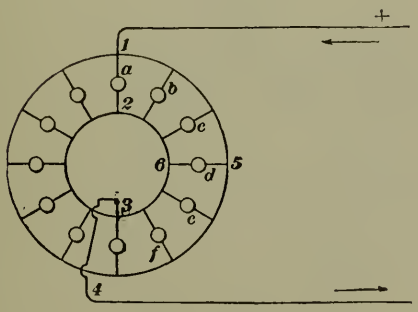
Spiral Loop.



Tree System.

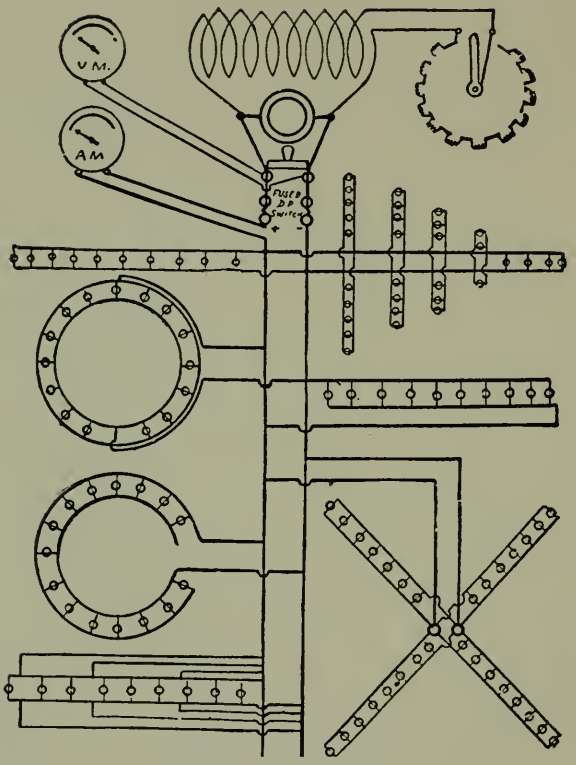


Three-Wire Central Station Distribution



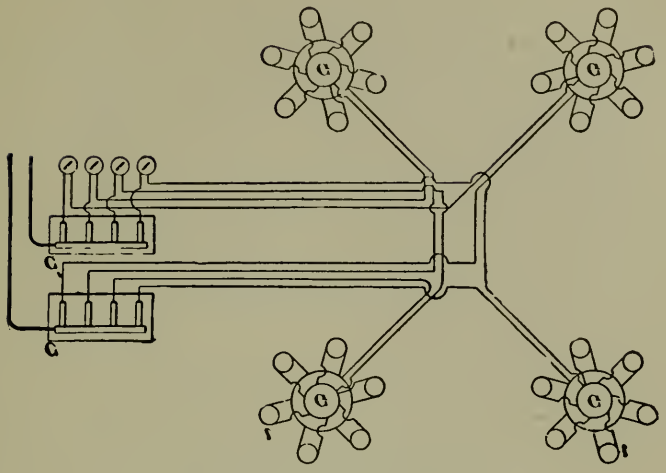
Closet System.

FIG. 195.—Distribution systems.

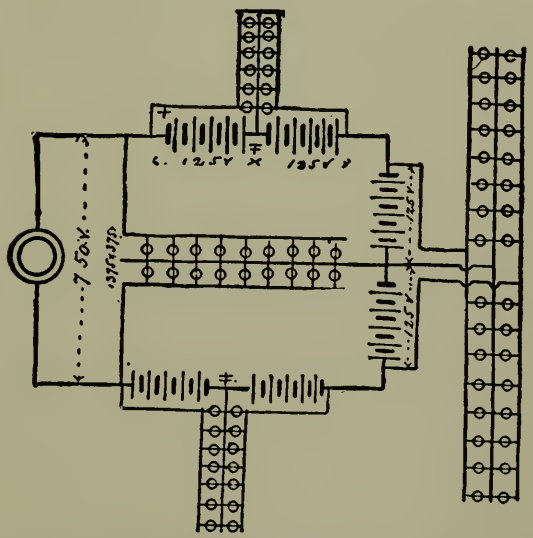


Two-Wire Distribution.

FIG. 196.—Distribution systems.

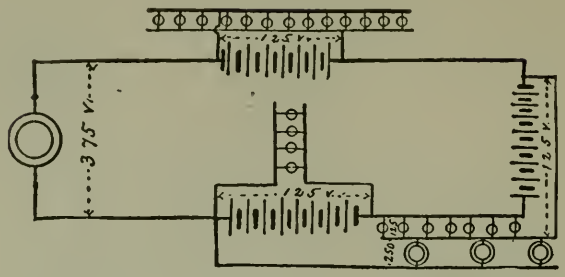


Closet System of Wiring.

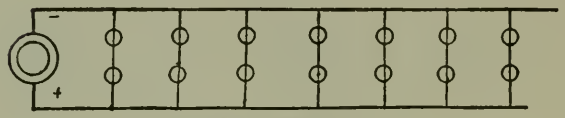


Series Distribution, Storage Battery, Three-Wire Sub-station.

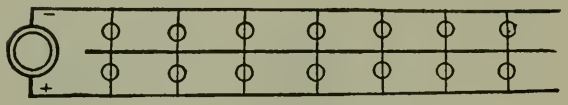
FIG. 197.—Distribution systems.



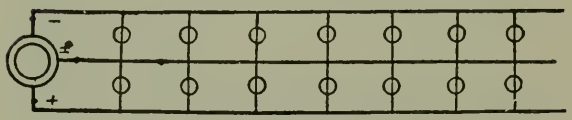
Series Distribution, Storage Battery, Sub-station.



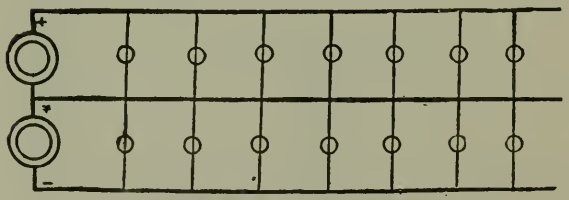
Series—Multiple.



Series—Multiple, with Neutral.

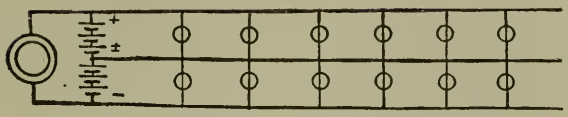


Three-Wire, with Three-Brush Dynamo.

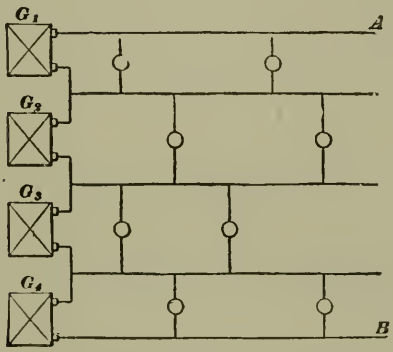


Three-Wire, Two Dynamos.

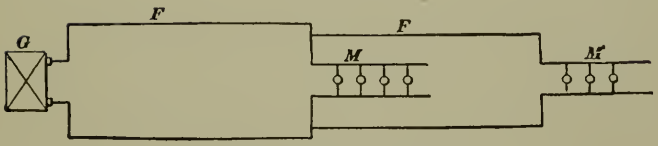
FIG. 198.—Distribution systems.



Three-Wire, Storage Battery.



Five and Seven-Wire Systems.



Feeder and Main System.

FIG. 199.—Distribution systems.

SECTION XII

CONSTANT CURRENT DISTRIBUTION

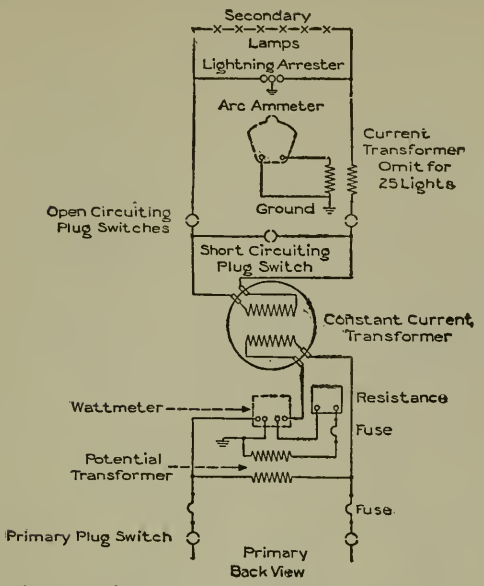


FIG. 200.—Panel and connections for series arc lighting system with constant-current transformers.

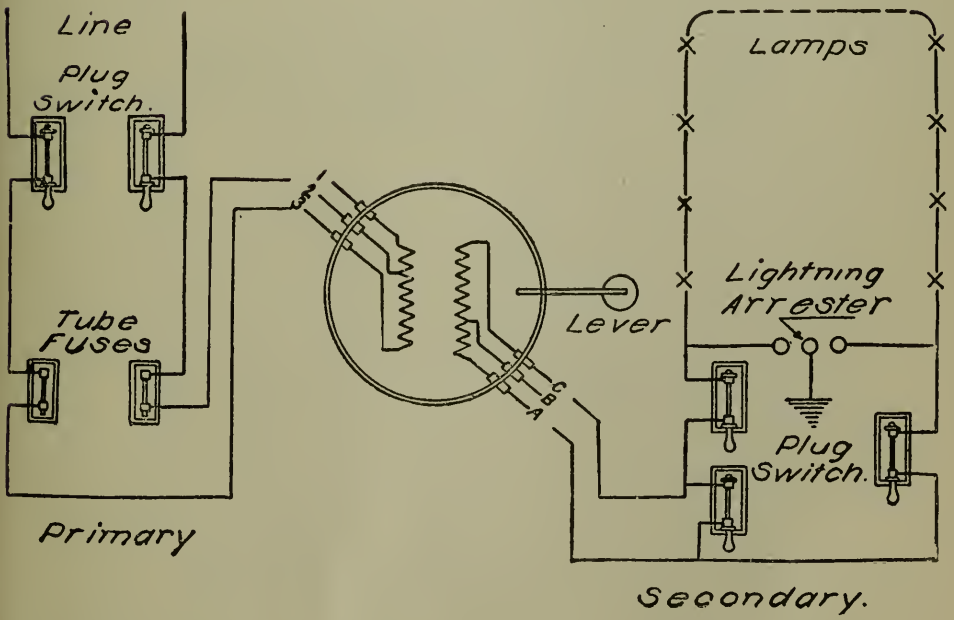


FIG. 201.—Connections for a 25-lamp constant-current transformer. For 60 per cent. load, connect 1 and 3 to the line and B and C to the load; for 80 per cent. load, connect 1 and 3 to the line and C and B to the load; for full load, connect 2 and 3 to the line and A and B to the load.

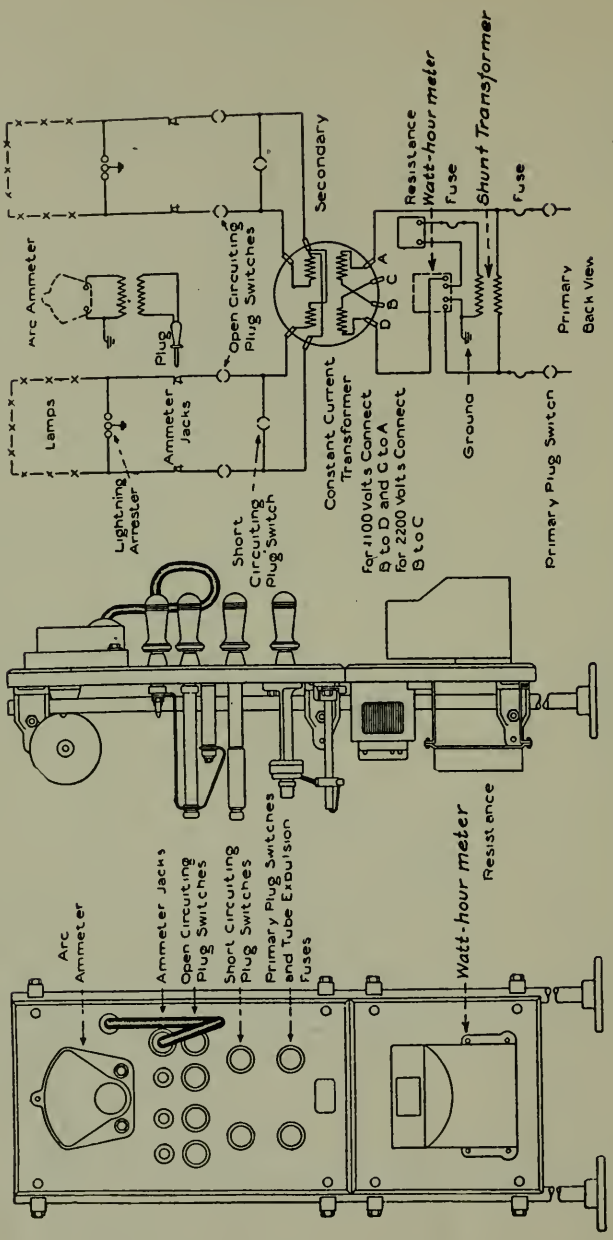


FIG. 202.—Panel and connections for double-circuit arc lighting system with constant-current transformer.

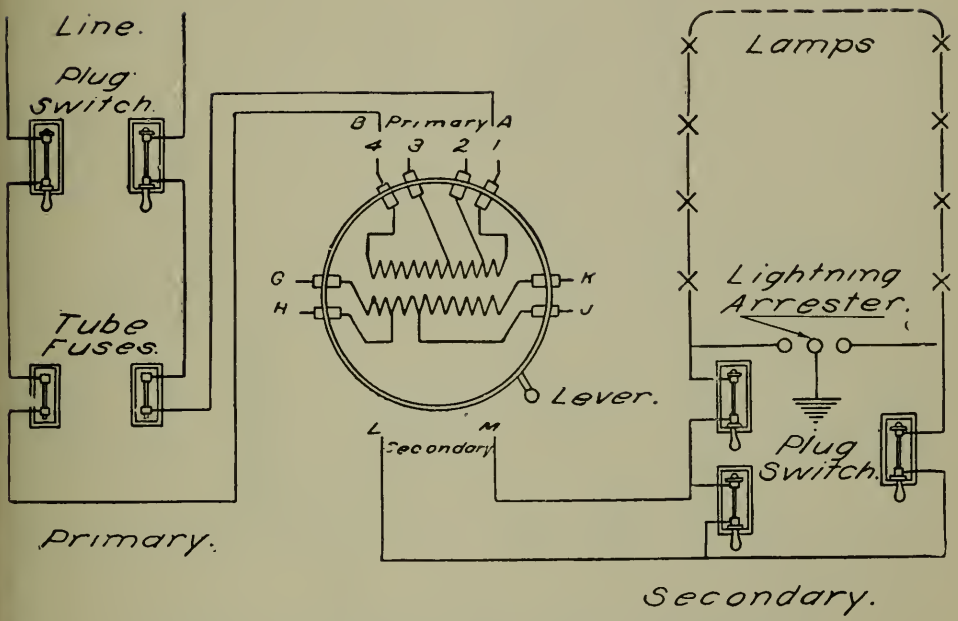


FIG. 203.—Connections for 50-lamp constant-current transformer.
For 60 per cent. load, connect 1 and 4 to the line and J and K to the load.
For 70 per cent. load, connect 1 and 4 to the line and H and K to the load.
For 80 per cent. load, connect 1 and 4 to the line and G and K to the load.
For 90 per cent. load, connect 2 and 4 to the line and G and K to the load.
For 100 per cent. load, connect 3 and 4 to the line and G and K to the load.

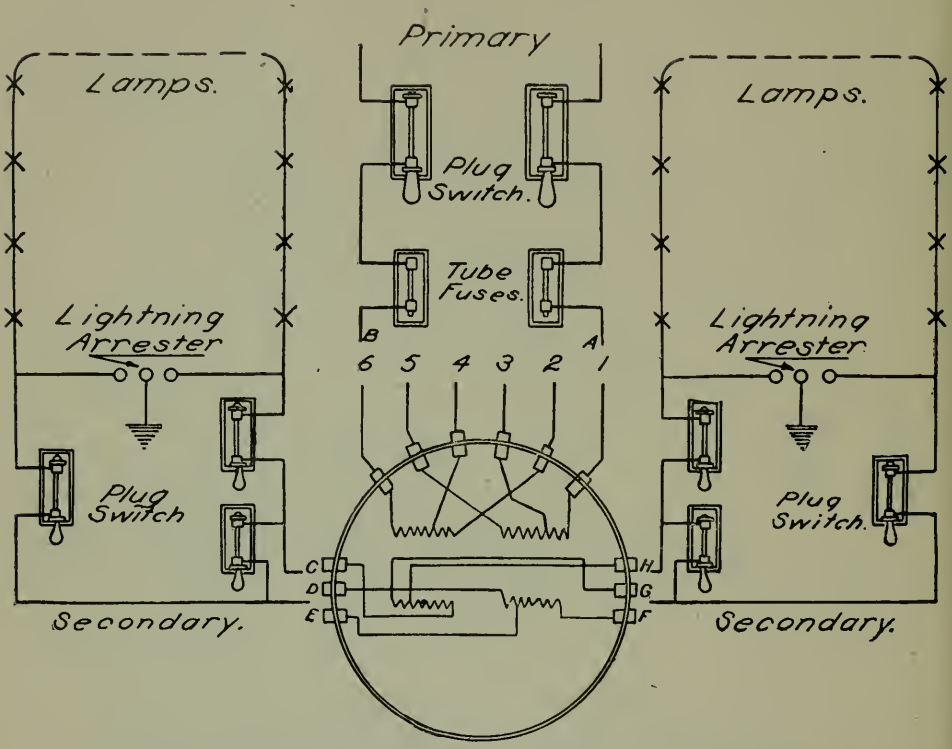


FIG. 204.—Connections for 100-lamp constant-current transformer.

For 60 per cent. load, connect A to 1, B to 6, 2 to 5, load between C and E, F and H.
For 70 per cent. load, connect A to 1, B to 6, 2 to 5, load between C and E, F and G.
For 80 per cent. load, connect A to 1, B to 6, 2 to 5, load between C and D, F and G.
For 90 per cent. load, connect A to 3, B to 6, 2 to 5, load between C and D, F and G.
For 100 per cent. load, connect A to 3, B to 6, 4 to 5, load between C and D, F and G.

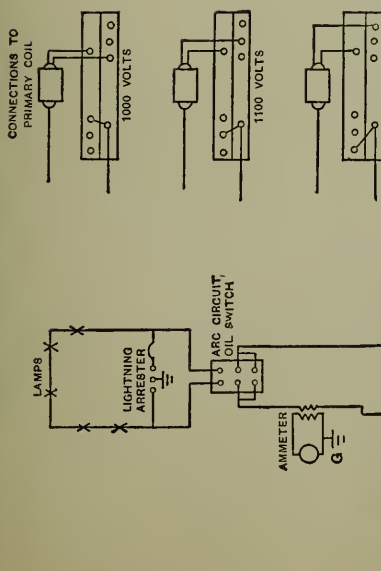


FIG. 205.—Connections for a series arc lighting system using a 75-lamp constant-current transformer.

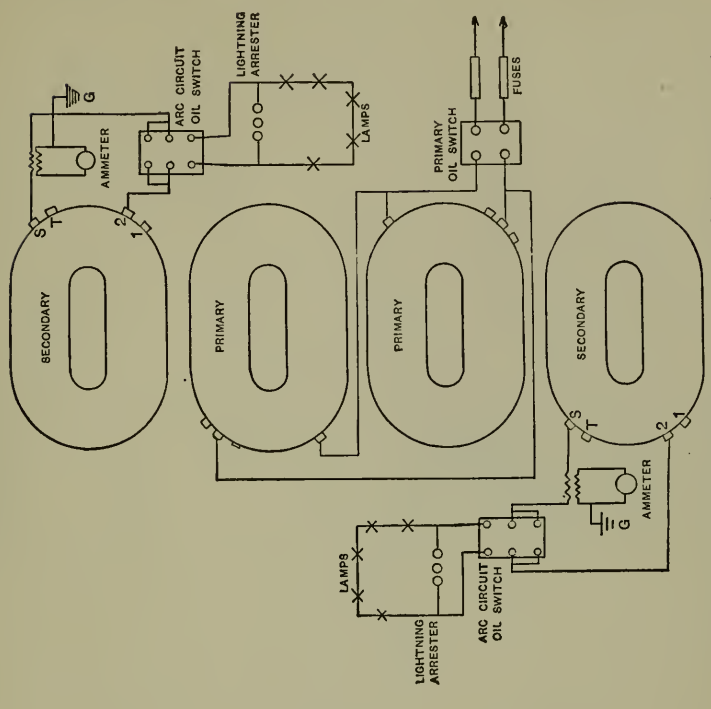


FIG. 206.—Connections for a series arc lighting system using 1000-lamp constant-current transformer.

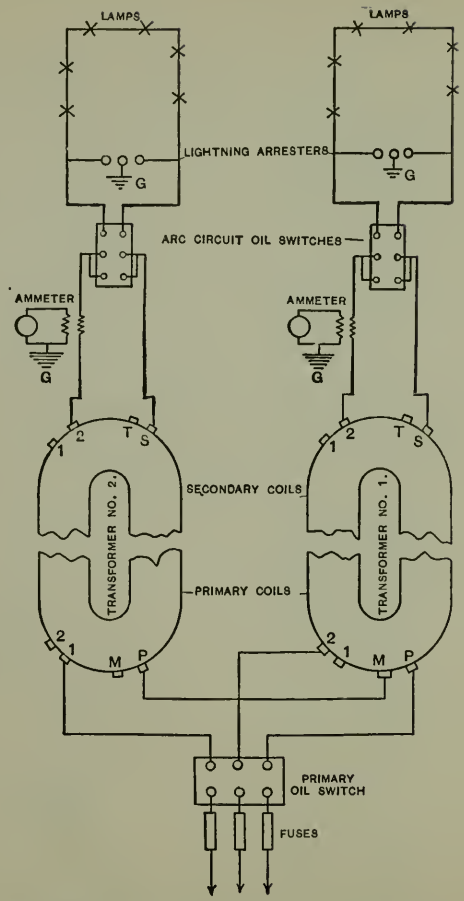


FIG. 207.—Connections for a series arc lighting system using two constant-current transformers connected to a three-phase system. Load must be balanced.

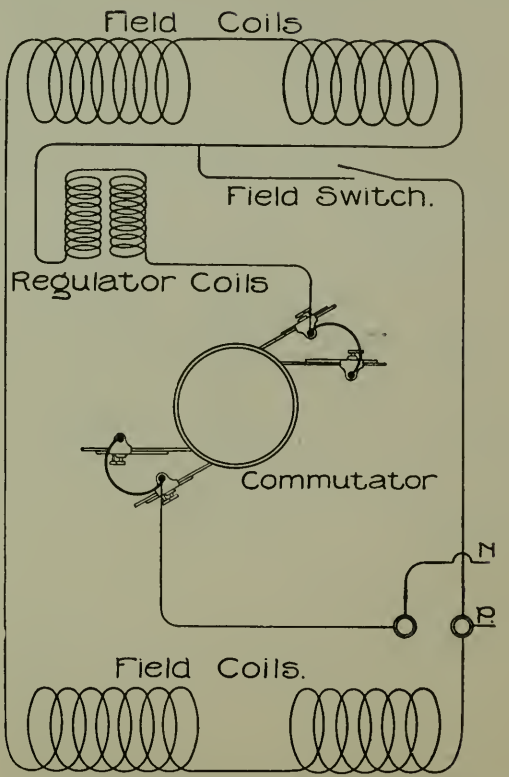


FIG. 208.—Connections of a Wood generator for direct-current arc lighting systems.

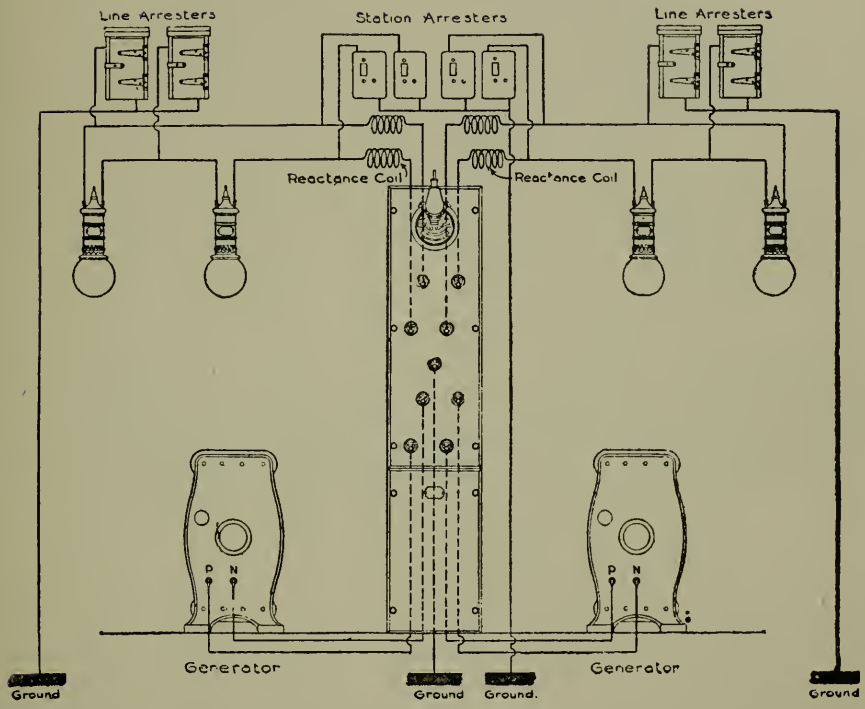


Fig. 209.—Connections for a direct-current arc lighting system using Wood generators.

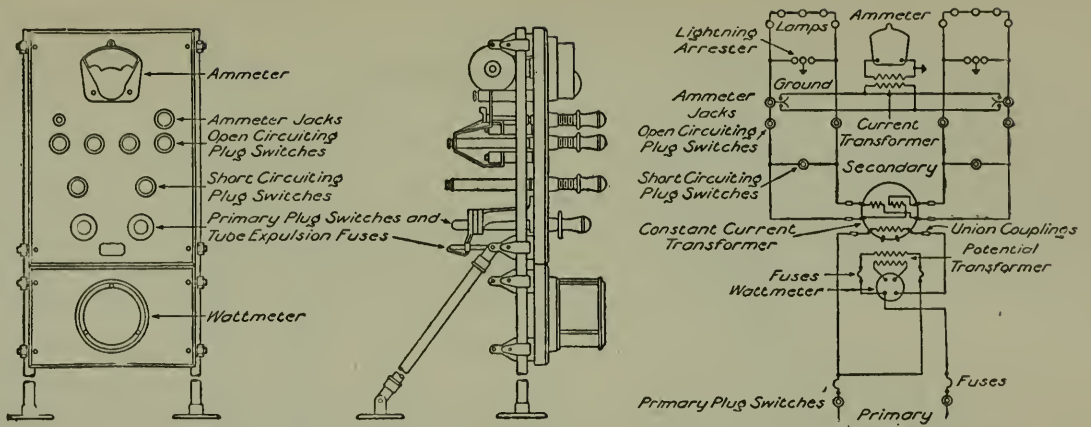


FIG 210.—Panel and connections for series incandescent lighting system using constant-current transformers.

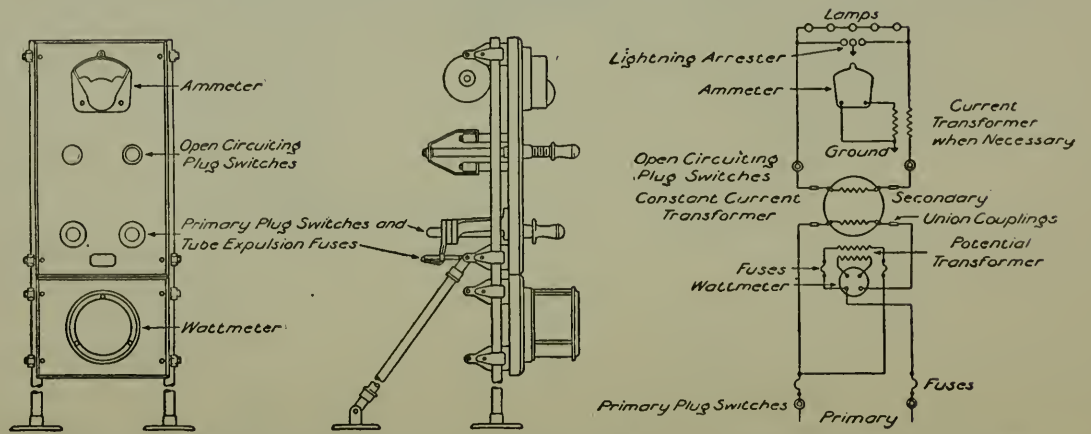


FIG. 211.—Panel and connections for double-circuit series incandescent lighting system using constant-current transformers.

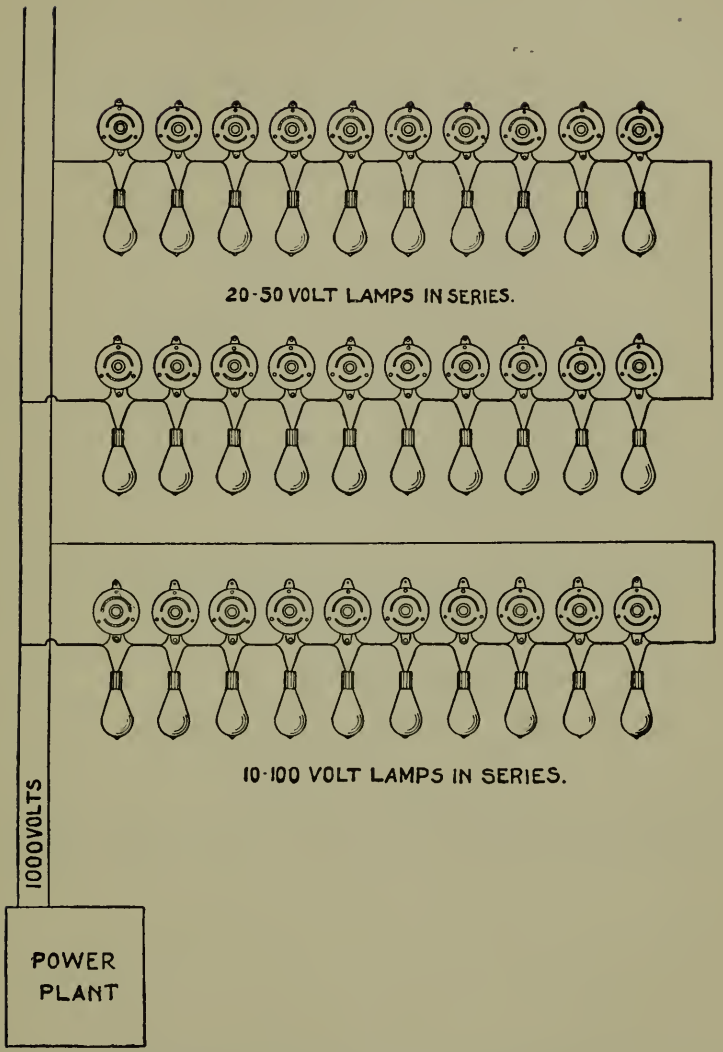


FIG. 212.—Series incandescent lighting system, each lamp shunted by a reactance coil.

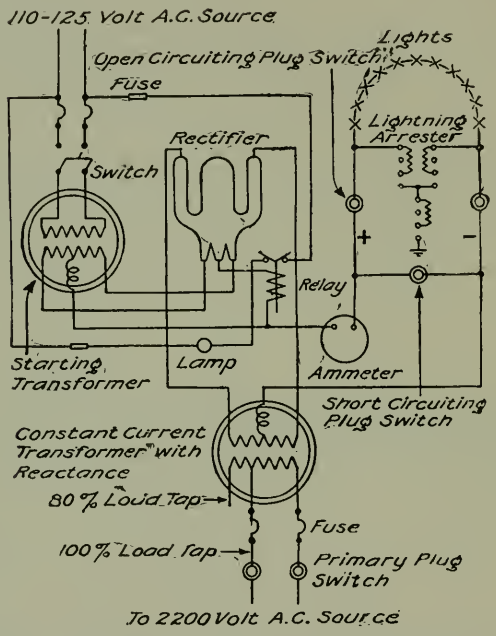


FIG. 213.—Direct-current arc lighting system working from an alternating current supply through a constant-current transformer and a mercury arc rectifier.

SECTION XIII

LAMP MECHANISM CONNECTIONS

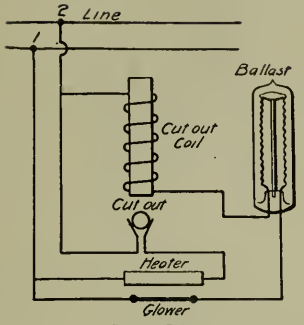


FIG. 214.

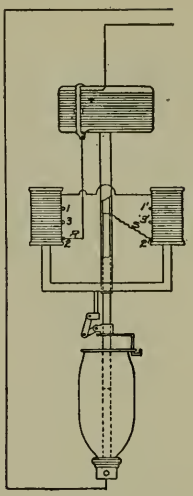


FIG. 215.

FIG. 214.—Internal connections of a single glower and Nernst lamp. At the beginning the resistance of the glower is very high so that very little current is carried by the cut-out coil in series with it. The heater raises the temperature of the glower, and as the temperature goes up its resistance decreases until the current reaches such a value that the cut-out coil opens the heater circuit. The ballast is a resister with a high temperature coefficient of resistance that tends to prevent fluctuations in the current, due to variation in the voltage.

FIG. 215.—Internal connections of direct-current arc lamp for operation on multiple circuits.

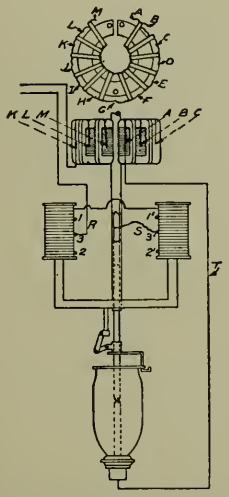


FIG. 216.—Internal connections of an alternating-current arc lamp for operation on multiple circuits.

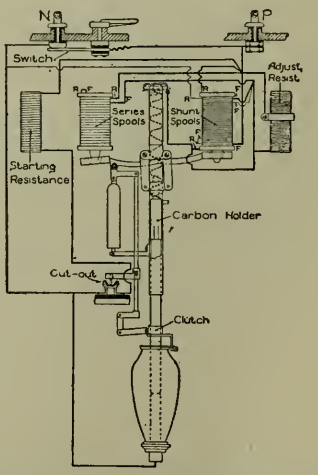


FIG. 217.—Internal connections of a direct-current arc lamp for series operation

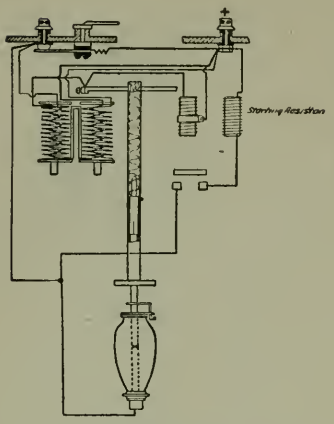


FIG. 218.—Internal connections of a direct-current arc lamp for series operation.

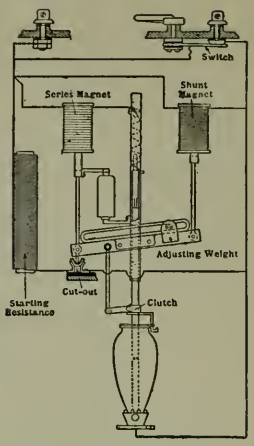


FIG. 219.—Internal connections of an alternating-current arc lamp for series operation.

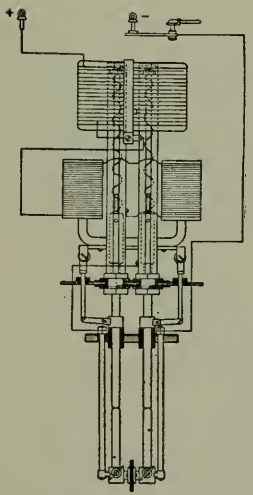


FIG. 220.—Internal connections of a 200-volt lamp with two carbons in series.

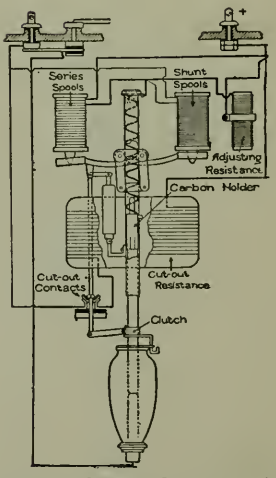


FIG. 221.—Internal connections of a series parallel direct-current lamp. Groups of five lamps in series are connected across 500-volts circuits.

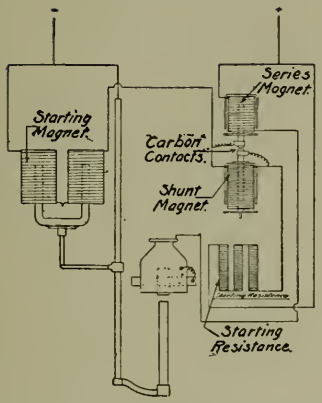


FIG. 222.—Internal connections of a magnetite arc lamp (General Electric).

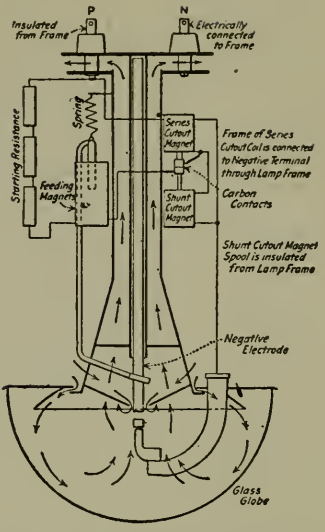


FIG. 223.—Internal connections of a magnetite arc lamp (Westinghouse Electric).

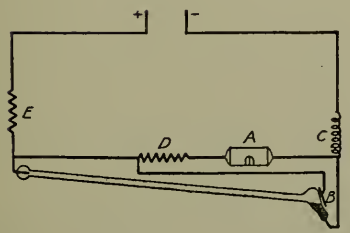


FIG. 224.—Connections of a self-starting mercury vapor lamp (Cooper-Hewitt).

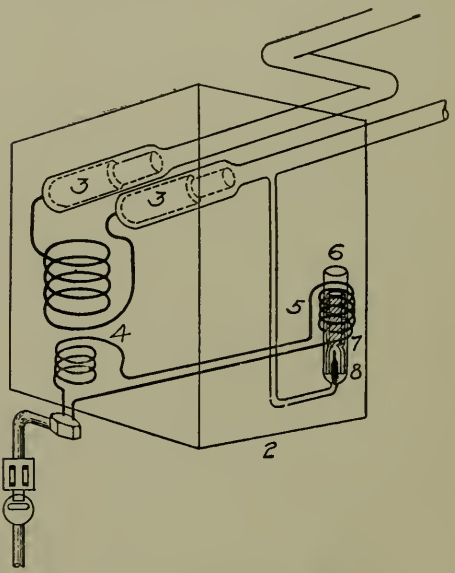


FIG 225.—Connections of a Moore tube vapor lamp. 7 is a feeder valve which is operated by a solenoid and maintains the constant pressure in the tube by admitting more gas when the vacuum increases.

SECTION XIV

RHEOSTATS AND CONTROLLERS

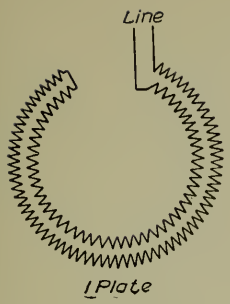


Fig. 226.

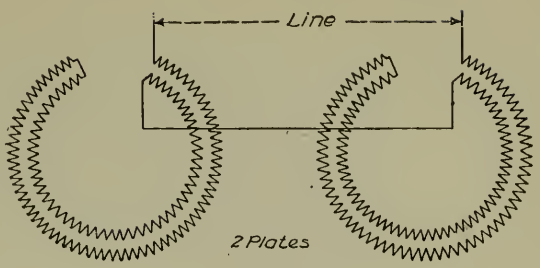


Fig. 227.

Fig. 226.—Connections for a dial rheostat with loop resister. Contact arm being arranged to slide directly over the surface of the resister.

Fig. 227.—Two units of the type shown in Fig. 226 connected in series.

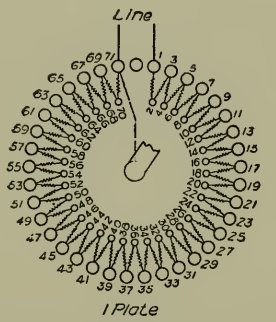


Fig. 228.—Connections of a dial rheostat resister arranged with contact buttons, over the surface of which the contact arm glides.

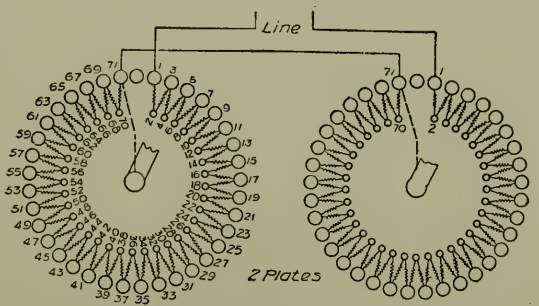


Fig. 229.—Two plates of the type shown in Fig. 228 connected in series.

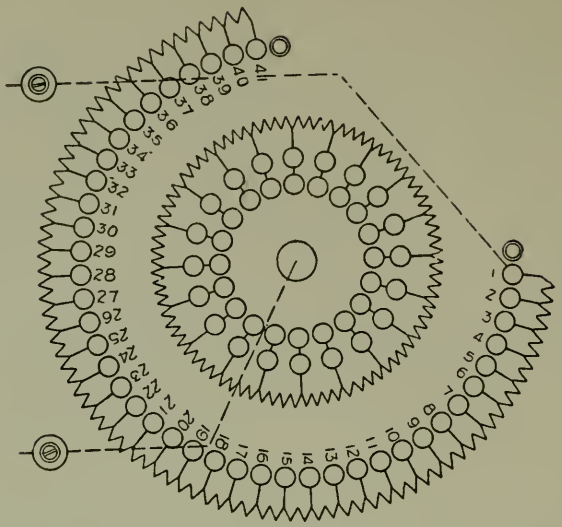


Fig. 230.—Connections of a two-arm dial rheostat resister. This rheostat is equipped with two arms, one short and one long; the short one connects the line with the inner circle of contact buttons, while the long one is insulated from the short one and connects the outer circle with the intermediate circle. The short arm is fastened rigidly to the hand-wheel. When both arms are in line and on the first point, all resistance is short-circuited. Rotation of the hand-wheel to the right carries the short arm around, leaving the long arm in its original position. When the short arm has made a half revolution, a projection on it strikes a pin in the long arm and carries it along, inserting the resister connected to the outer buttons. Movement in the opposite direction causes the short arm to carry the long arm with it.

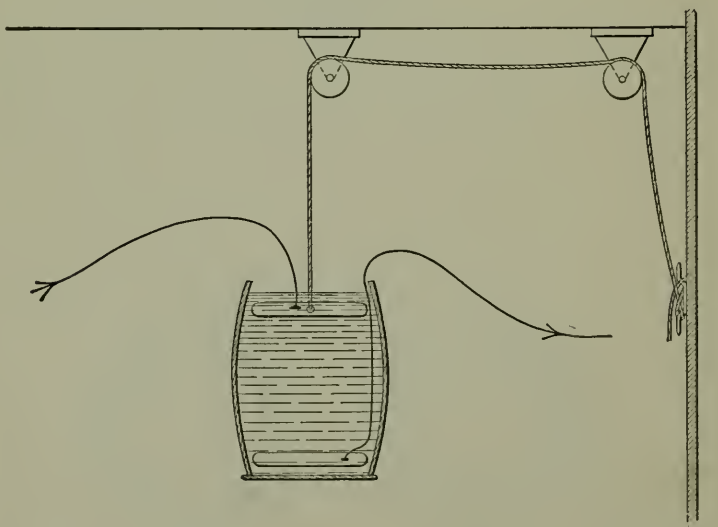


Fig. 231.—Barrel rheostat. For calculation of dimensions, etc., see "Standard Handbook for Electrical Engineers," Section 3.

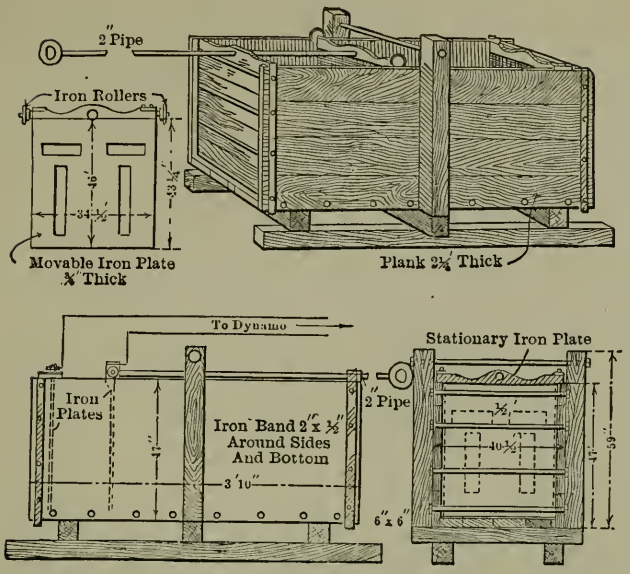


FIG. 232.—Water rheostat. For calculation of dimensions, etc., see "Standard Handbook for Electrical Engineers."

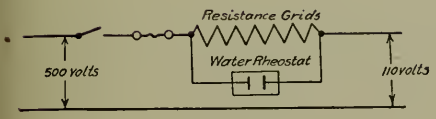


FIG. 233.

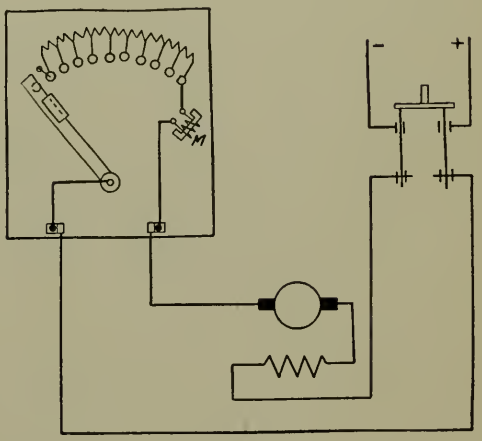


FIG. 234.

FIG. 233.—Home-made rheostat of large current-carrying capacity for reducing 500-volt circuit to 110 volts. The resister grids are of the type used on railway cars. The voltage can be varied by the water rheostat.

FIG. 234.—Connections for typical series-motor starter, with no load release, M, in series with the motor. The electromagnet, M, holds the rheostat arm on the last point while the motor is in operation, and if the circuit is opened at any point, this magnet releases and the coil spring returns the arm to the off position.

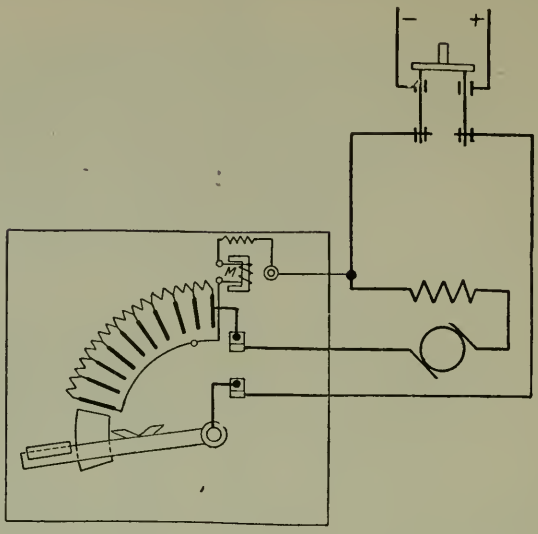


FIG. 235.—Typical series-motor starter with no-load release across the line.

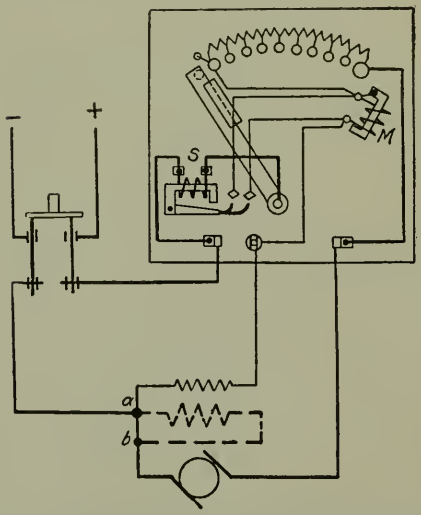


FIG. 236.—Typical shunt or compound motor starter with no-load release in series with the shunt field winding, and an overload release in series with the armature. The series winding for a compound motor is shown dotted, connected between the points a and b, instead of the solid line. If the current in the overload, S, which is in series with the armature, exceeds a predetermined value, the overload draws up its armature and short-circuits the electromagnet, M, which then releases the rheostat arm.

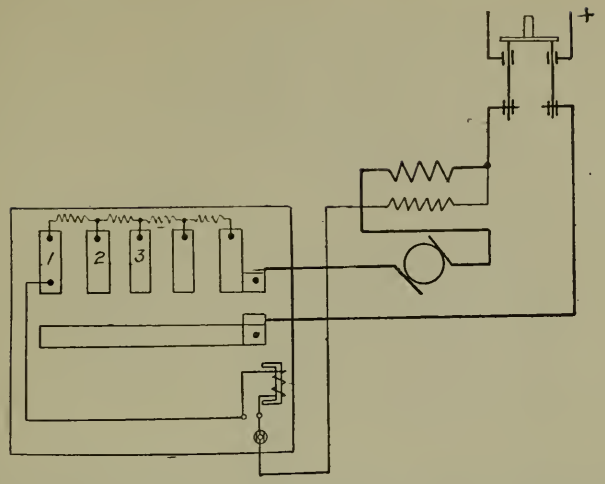


FIG. 237.—Multi-switch starter for a compound motor. No-load release in series with the shunt field winding. In starting, resistance is cut out of the armature circuit by closing switches connected between the plus side of the line and the contacts 1, 2, 3, etc., the last switch being held in position by the no-load release. The switch levers are mechanically interlocked so that when the last one is released by no-load magnet, the other ones are pulled out with it.

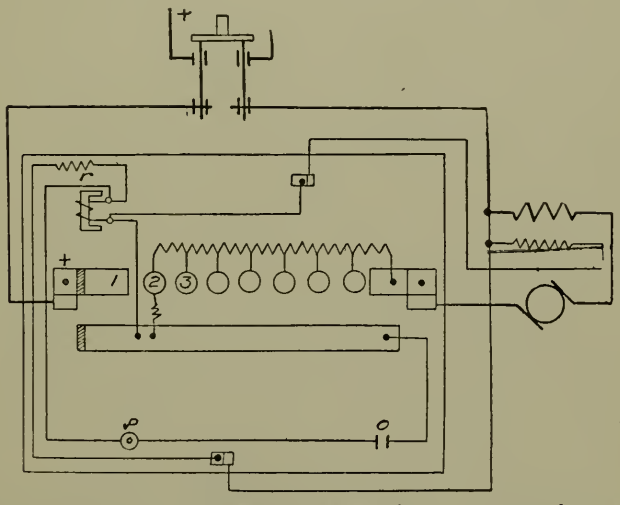


FIG. 238.—Connections of a multi-switch starter for a compound motor with no-load release connected across the line. The switches are mechanically interlocked so that they can only be closed in the right order, and each one is held closed by the one preceding it. Switch 1 is held by the no-load release, and the last switch, when open, short-circuits the no-load release at the point 0; therefore, when starting this short-circuit must be opened by pressing the push button, P, and holding it until all switches have been closed, the last one opening the circuit at 0.

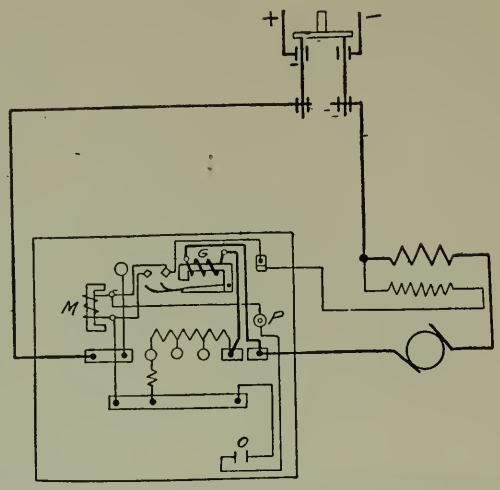


Fig. 239.—Connections for multi-switch starter equipped with no-load and over-load releases. The starter operated precisely as the one shown in Fig. 238. An excess of current in the main circuit will close the over-load relay, G, and short-circuit the no-load release, M, which allows the first switch to drop out, and the others being mechanically interlocked with each other, will drop out in succession.

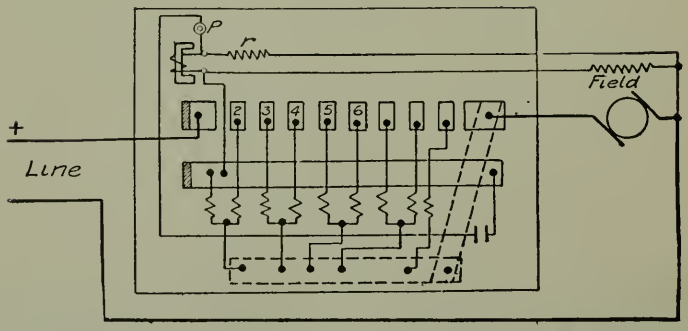


Fig. 240.—Connections for a multi-switch starter used with parallel starting resistances. Closing the switches in rotation from left to right, connects more and more resistance in parallel until up to the last step, where the motor is connected direct to the line.

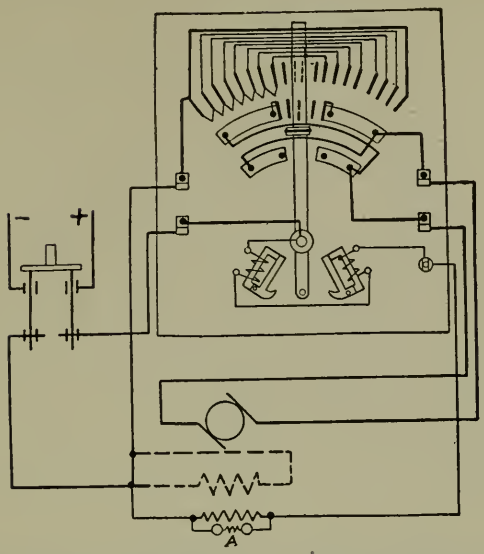


FIG. 241.—Connections for a full reversing shunt or compound starter, no-load releases being in series with the shunt field. The compound field winding is shown dotted.

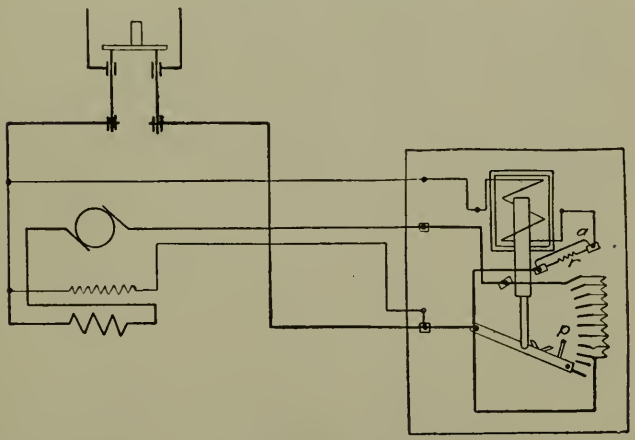


FIG. 242.—Connections for a self-starter of the sliding-contact type. Closing the main switch energizes the solenoid which slowly raises the rheostat arm against the action of a dash pot. At the end of its stroke, the projection, p, on the rheostat arm raises the contact arm, a, inserting the resistance, r, in series with the solenoid; in this manner cutting down the current to that value necessary to hold the plunger in its highest position.

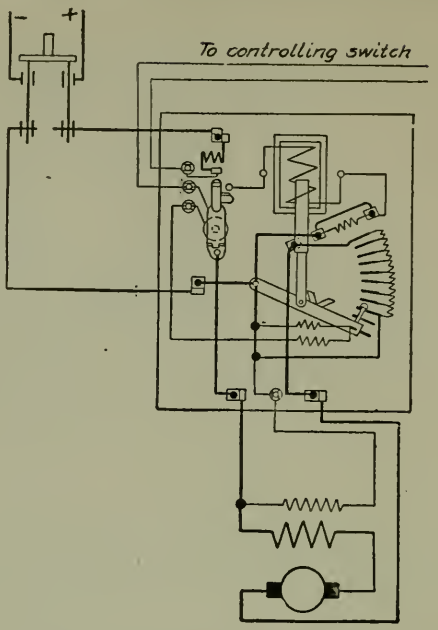


FIG. 243.—Connections for self-starter with an auxiliary switch controlled from a distance. If the main switch is closed, the motor may be started or stopped fron a distance by a single-pole switch. The operation is exactly the same as the starter shown in Fig. 242, except that the circuit of the solenoid magnet can be opened or closed at a distance by operating the auxiliary magnet switch, the main switch being left closed.

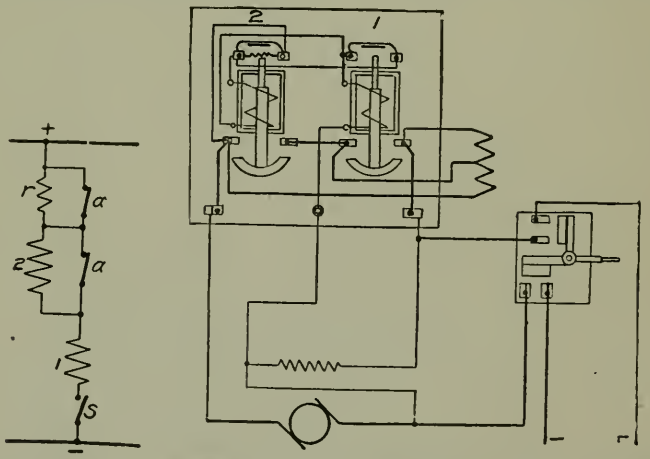


FIG. 244.—Connections for a two-solenoid self-starter controlled by a float switch. For operation of the float switch see Fig. 256. The main switch, which may be connected to a float in a tank, closes the main circuit with a resistance in series with the motor; at the same time the solenoid, 1, is energized, while solenoid, 2, is short-circuited by the contact piece at the top of solenoid 1. When 1 closes, short-circuiting part of the starting resistance, it lifts the contact piece at the top, and thus energizes solenoid 2. Solenoid 2, in closing, short-circuits all the starting resistance and lifts the contact at the top, inserting a resistance in series with the solenoid windings. The control circuit is shown at the left. S represents the float switch; 1, the winding of solenoid 1; a_1, the contact piece for solenoid 1; 2, solenoid 2; a_2, contact piece for solenoid piece over solenoid 2, and r, the resistance inserted in series with the solenoids when the motor is running.

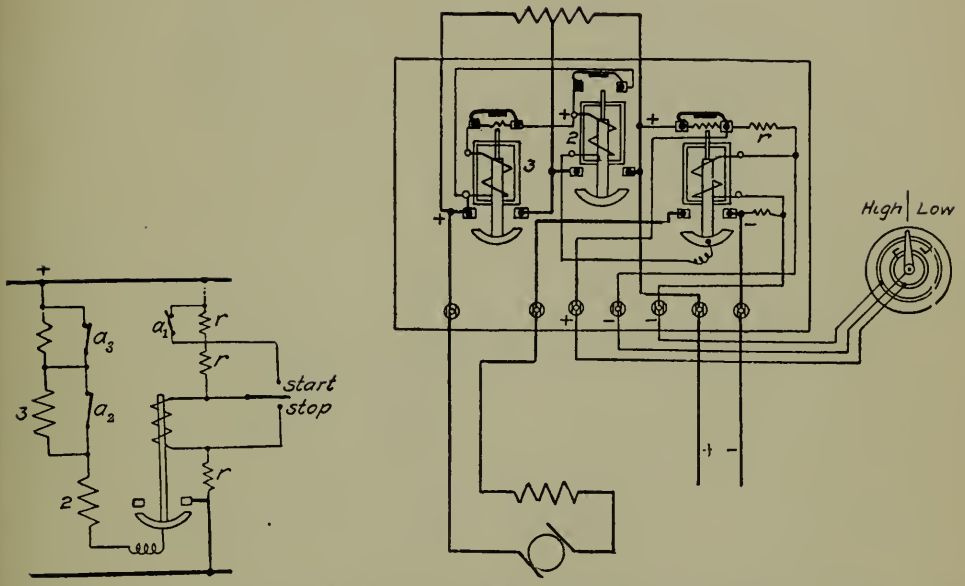


FIG. 245.—Connections for a two-step self-starter operated by a pressure regulator. The control circuits are shown at the left, 1, 2 and 3 representing the solenoids; a_1, a_2, and a_3 the corresponding contact pieces above the plungers; r, resistances. The pressure governor is a sort of a pressure gage equipped with contacts. When the pressure reaches a certain minimum value, the "start" contact is closed, energizing solenoid 1. In closing, solenoid 1 connects the winding of solenoid 2 across the line. The plunger of solenoid 2 opens the contact arm a_2, inserting solenoid 3 in circuit, which in turn opens contact a_3, inserting the resistance, r, in series with the windings 2 and 3. When the pressure reaches a predetermined maximum value, the stop contact is closed and solenoid 1 short-circuited, whereupon all solenoids drop out, leaving the motor on open circuit.

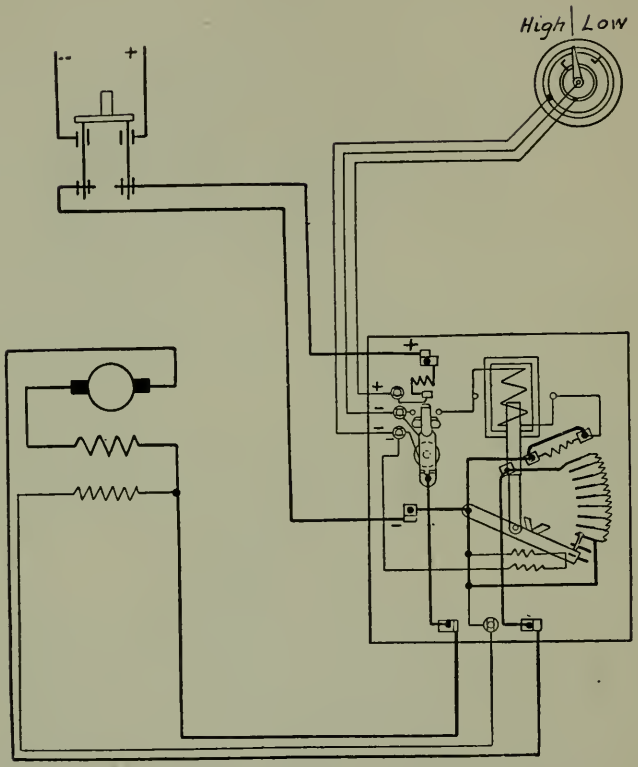


Fig. 246.—Connections for a self-starter of the sliding-contact type operated with an auxiliary electromagnet controlled by a pressure regulator of the type described in Fig. 245. The operation is the same as the starter shown in Fig. 243, except that the auxiliary magnet is arranged to hold itself in circuit until short-circuited by the pressure regulator when the predetermined maximum pressure is reached.

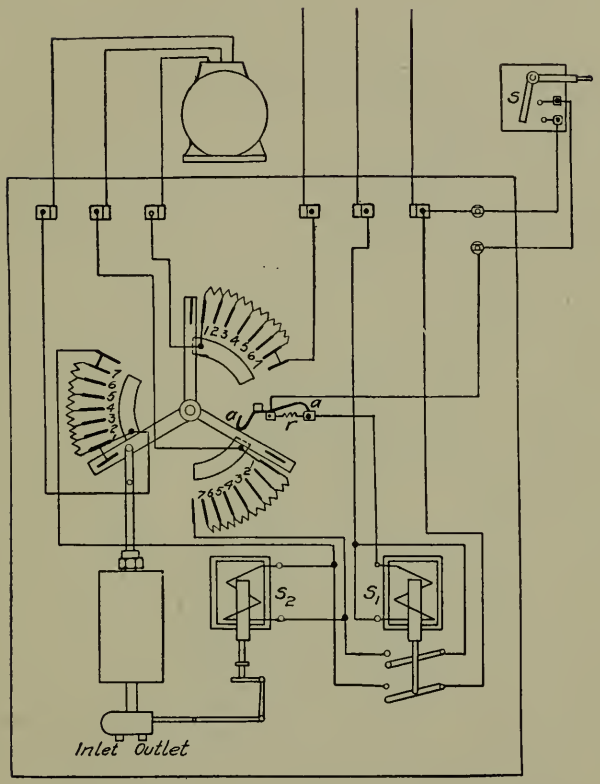


FIG. 247.—Connections for three-phase induction motor self-starter. The main switch, S, is operated by a float in the tank. Closing the switch, S, energizes the main solenoid, S, which opens the inlet valve to the plunger which acts to cut out the starting resistance. In turning around, one of the rheostat arms opens the contact piece, a, inserting the resistance, r, in series with the solenoid, S_1. The plunger which actuates the rheostat may be operated by air or water.

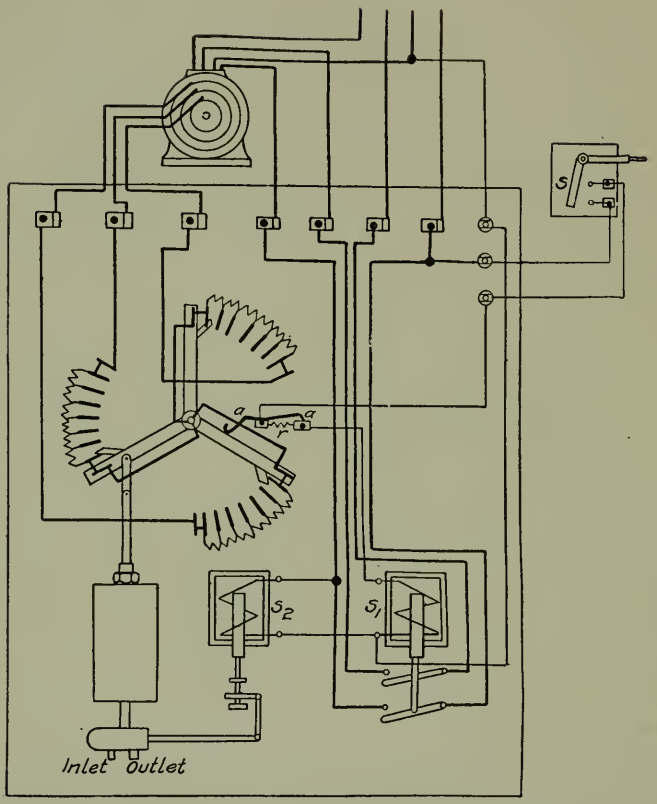


FIG. 248.—Connections for a two-phase induction motor, self-starter. This starter works exactly the same as the one shown in Fig. 247, except that the resistance is inserted in the secondary circuit instead of the primary.

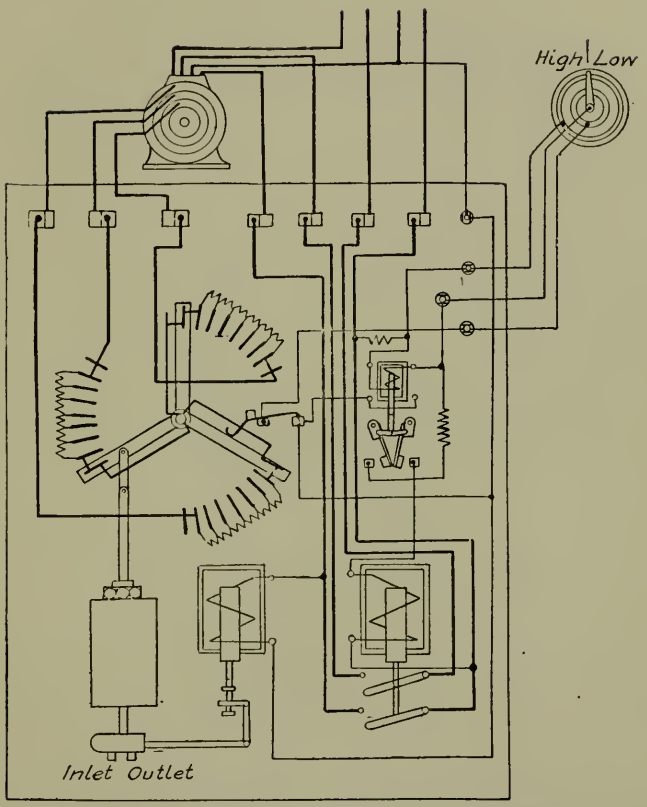


FIG. 249.—Connections for a two-phase induction motor self-starter connected in the secondary, arranged for operation by air pressure regulator, through auxiliary magnetic switch.

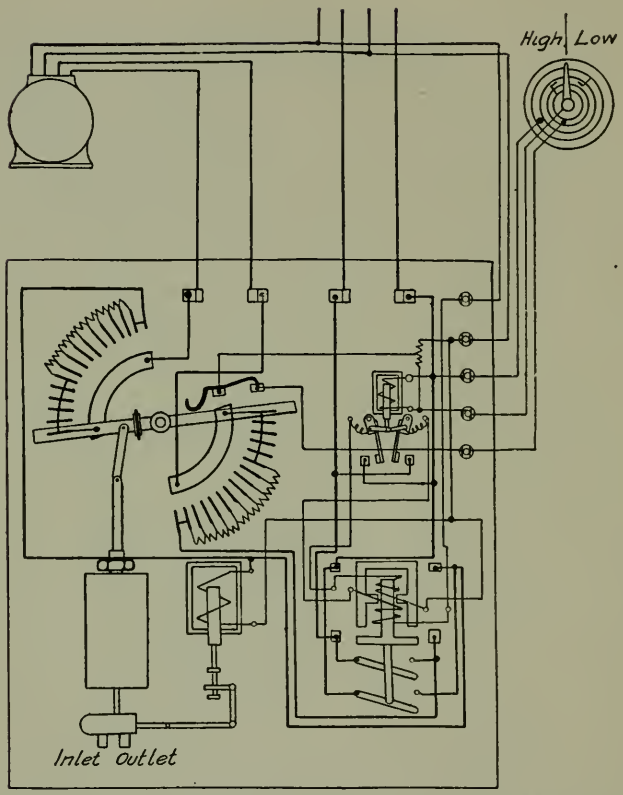


FIG. 250.—Connections for a two-phase induction motor, self-starter, with starting resistance connected in the primary circuit. The operation is exactly the same as that of the starter shown in Fig. 249.

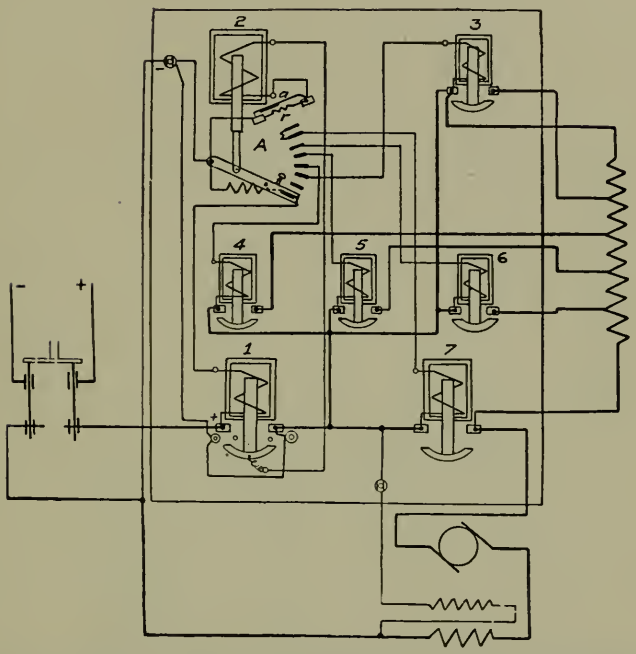


FIG. 251.—Connections for multiple solenoid, self-starter. Connections for the control circuit are shown in Fig. 252. When the main switch is closed, solenoid 1 is energized. Upon closing, solenoid 1 energizes solenoid 2 and connects the motor in series with the starting rheostat to the line. Solenoid 2 raises the rheostat arm, A, against the pull of a dash pot, and as the contacts are passed over, the solenoid switches 3, 4, 5, 6 and 7 are closed in rotation, each short-circuiting corresponding sections of the rheostat. When the arm reaches the end of its stroke, all the switches, except 7, have dropped out, and the resistances are connected in series with solenoids 1, 2 and 7 in the following manner: When the contact arm, A, moves off of the first contact, resistance is connected in series in 1. When it moves to the last contact, resistance is connected in series with 7, and the resistance, R′, is connected in series with 7 and the resistance, r, in series with 2. The action of the solenoid 2 was explained in Fig. 242.

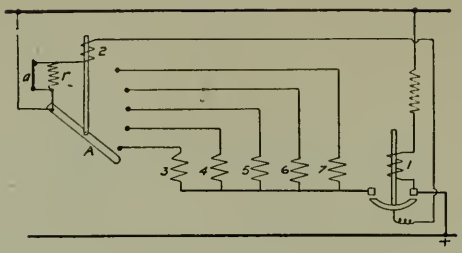


FIG. 252.—Control circuits of the starter shown in Fig. 251.

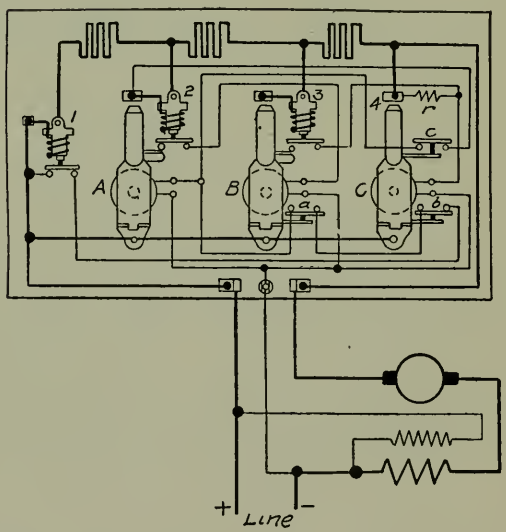


FIG. 253.—Connections for clapper type three-switch self-starter with current limit relays. When the main switch is closed, the motor is connected to the line through the starting rheostat, and when the current decreases to a predetermined value, the current limit relay, 1, closes and the switch magnet, A, is energized, which closes, short-circuiting the first section of the rheostat and energizing current limit relay 2. Again, when the current decreases to a predetermined value, the current limit relay closes, energizing magnet, B, etc. When magnet B is energized, the magnet winding, A, is short-circuited; likewise, when C is energized, B is short-circuited. When the motor is running, the magnet C remains in circuit in series with the resistance, r, which is inserted by opening the contact, c, when the magnet closes. The contacts a and b are interlocked and open when the corresponding magnets B and C are closed, thus preventing the energizing of magnet A when either B or C are closed.

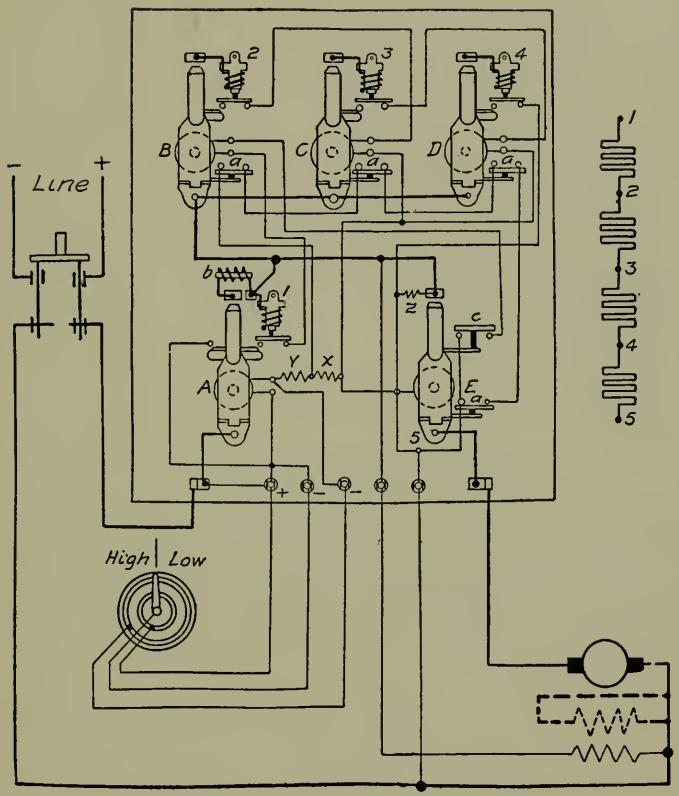


FIG. 254.—Connections for clapper type five-switch self-starter with current limit relays. The operation is similar to that of the starter shown in Fig. 255, except that the switches A and E remain closed while the motor is running.

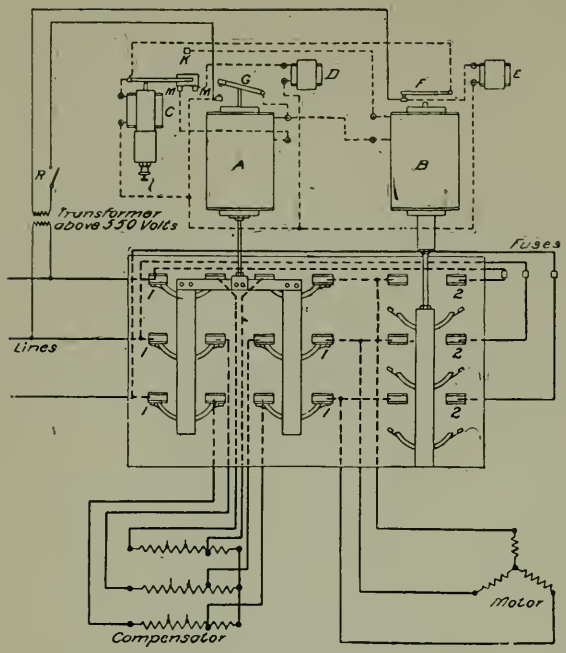


Fig. 255.

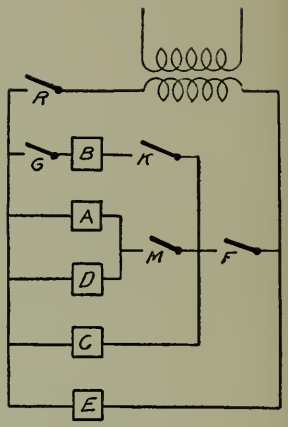


Fig. 256.

Fig. 255.—Connections for an induction motor, self-starter; oil switches 1 and 2 being operated by solenoids A and B. The control diagram is shown in Fig. 256. Switches G, M and F are normally closed. Closing the main switch, R, energizes trip magnets D, C and E, and the solenoid, A, which closes oil switch 1, connecting the motor to the starting taps on the compensator, and the compensator to the line. The closing of 1 opens G, and later, due to a dash pot, the magnet C opens M and closes K. Opening M de-energizes A and D, and D-trips 1, closing G; thus bringing B into operation, which closes oil switch 2, connecting the motor directly across the line.

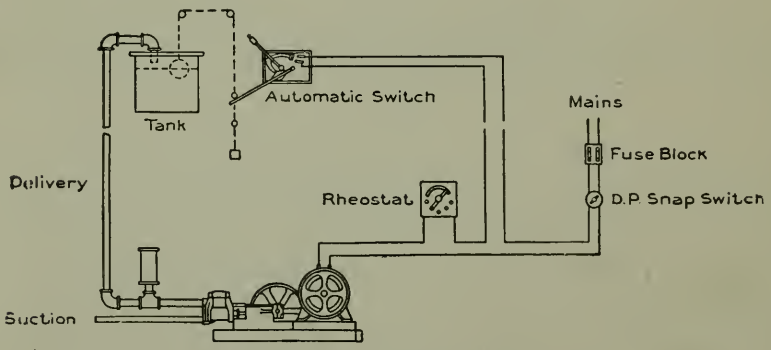


Fig. 257.—Arrangement for operating an auto-starter with an automatic switch to maintain constant level in a water tank.

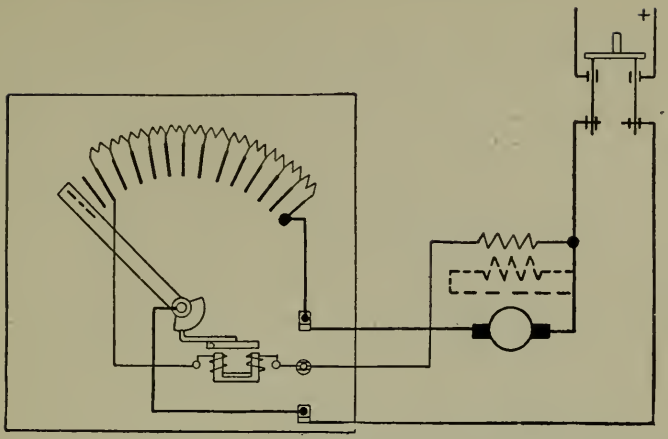


FIG. 258.—Connections for standard speed regulator. Rheostat in series with the armature. The no-load release holds the arm in any position it may be left, by means of a dog which fits into the notches corresponding to points on the rheostat. This arrangement makes it impossible to stop anywhere, except on the center of the contact, and whenever the voltage drops to zero, the regulator arm is released and returned to the off position by a coil spring.

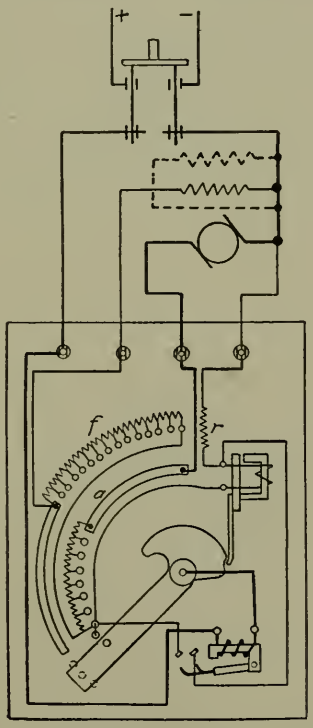


FIG. 259.—Connections for a compound speed regulator equipped with no-load and overload releases. Speeds below normal are obtained by inserting resistance in the armature circuit, and above normal by inserting resistance in the field circuit. The no-load release operates exactly as described in Fig. 258, and the overload, which is connected in series with the motor, operates by short-circuiting the no-load release.

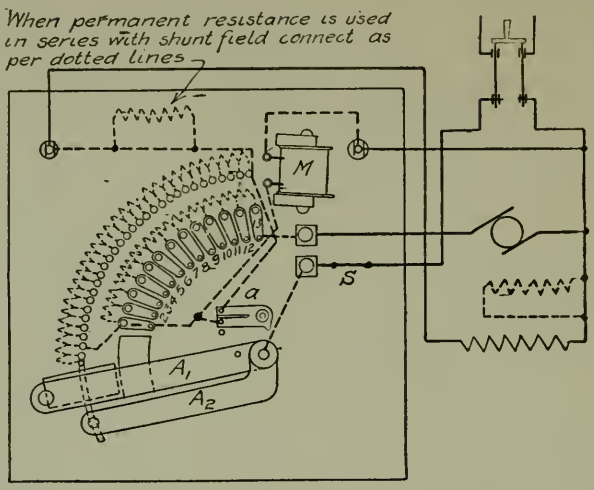


Fig. 260.—Connections for combination starter and speed regulator. In starting the motor, move the levers A_1 and A_2 to the right, gradually cutting out resistance in series with the armature, leaving the lever A_1 locked by the no-load release magnet M. To increase the speed, move lever A_2 to the left, inserting resistance in the field circuit. The field circuit enters the rheostat, and is joined permanently to one end of the field resister. From this point it has two paths: one through the field resister and the arm A_2, and the other through the switch a, the armature resister and the arm A_1. At the beginning, the resistance of the latter path is much smaller than the former, and at the end *vice versa*. When the lever A_1 comes into its final position, the switch a is opened, so that the only path for the field current is through the field resister, the resistance of the circuit being increased by moving the arm A_2 to the left. This rheostat can be equipped with an overload release connected between the points shown at S instead of the solid line.

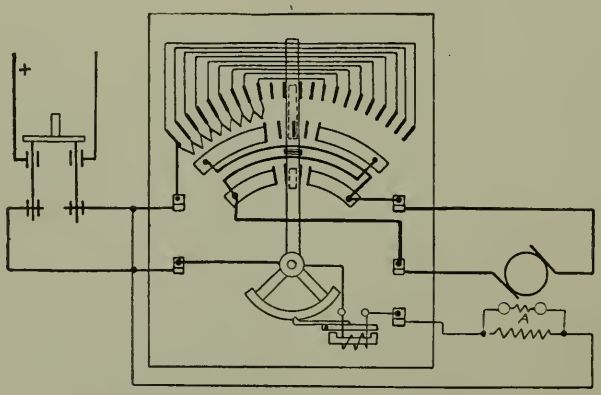


Fig. 261.—Connections for a full reverse speed regulator with no-load release.

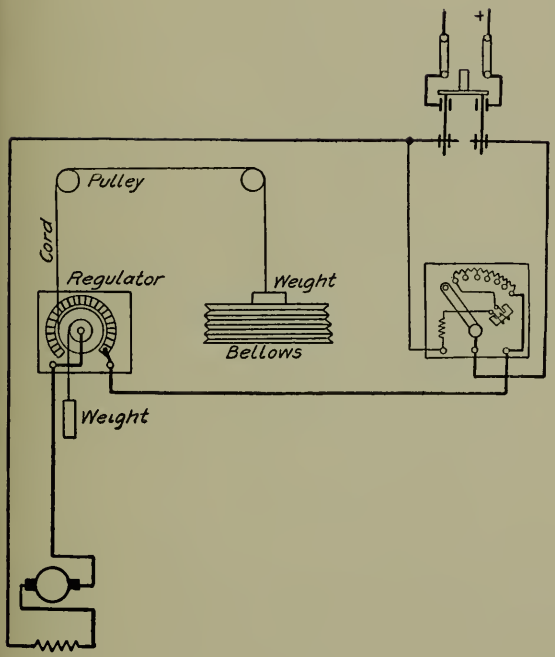


Fig. 262.

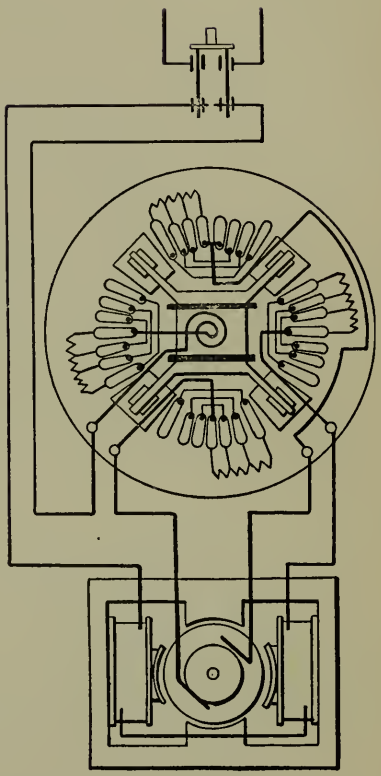


Fig. 263.

Fig. 262.—Connections for an organ regulator and starting box, the no-load release being connected across the line. Arrangement is shown for a series motor. There would be no change with a shunt motor, other than in the starting rheostat.

Fig. 263.—Connections for a self-starter with drum reversing switch adapted to elevator work.

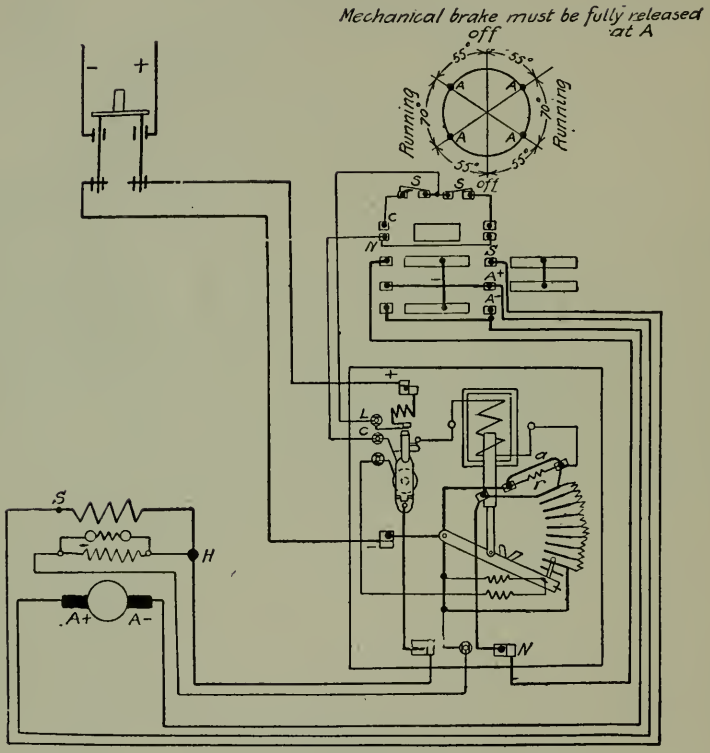

Mechanical brake must be fully released at A
off
Running
Running
55°
70°
A
S
off
C
N
A+
A-
L
a
H
W

Fig. 264.

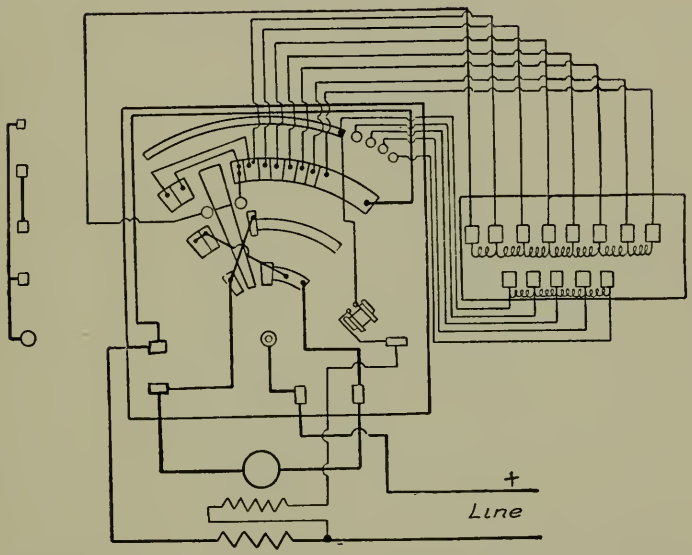


FIG. 265.—Connections for a compound automatic reversing printing-press controller. Moving the lever to the right gradually cuts out resistance in series with the armature until full speed is reached, when further movement in the same direction will insert resistance in series with the field circuit, increasing the speed above normal. Movement to the left of the dead contact will reverse the motor and allow it to run at slow speed.

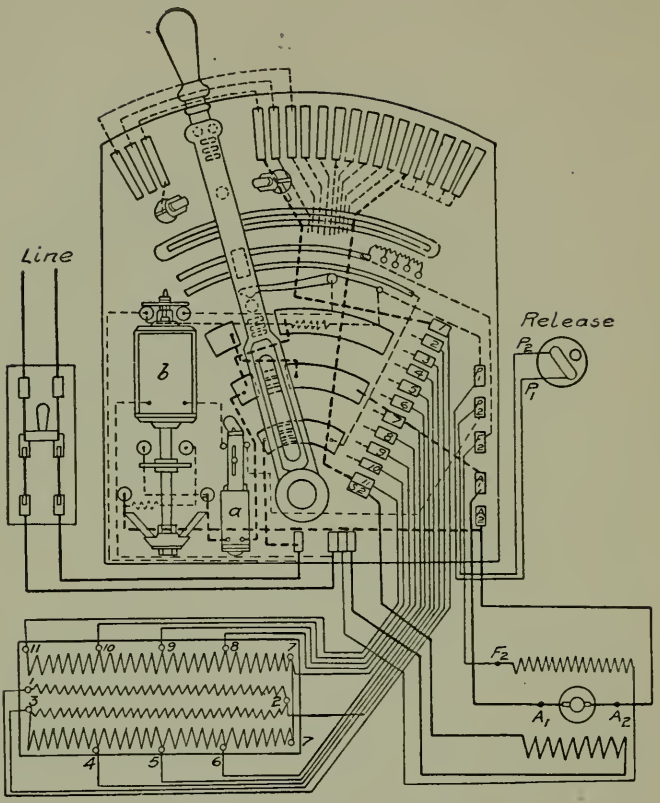


FIG. 266.—Connections for Carpenter's compound press controller. When the lever is in the off position, the solenoid switch, b, can be energized by operating the release shown at the right. This solenoid switch closes the main circuit through the starting resistance, which then can be cut out step by step by moving the starting lever to the right for forward operation, and to the left for backward operation. When the solenoid switch, b, closes, a resistance is inserted in series with its winding, thus cutting the current down to that value which is just sufficient to hold it in a closed position. The series overload relay, a, is arranged to cut out the solenoid, b, whenever predetermined current is exceeded. If the motor is stopped, it cannot be started.

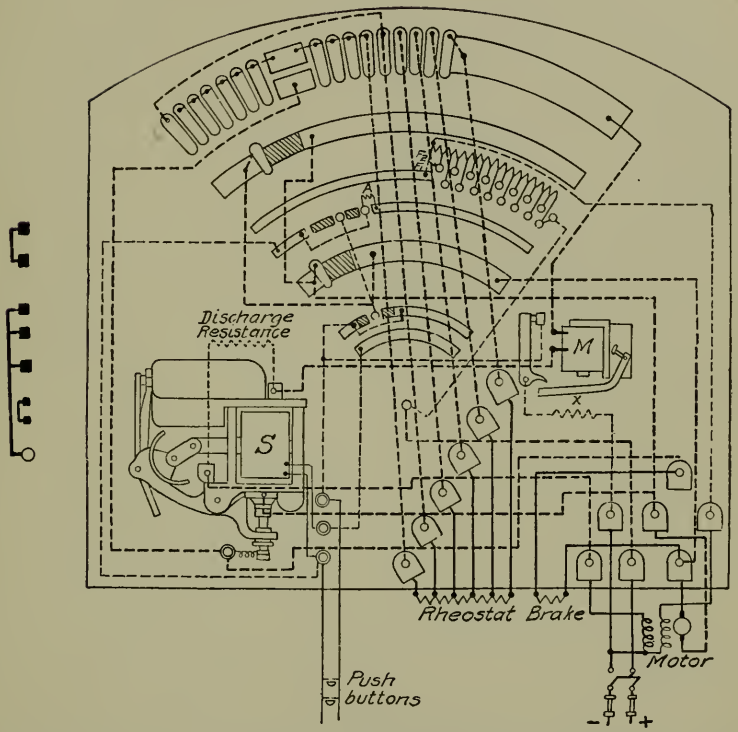


FIG. 267.—Connections for compound type printing press controller. The connections made by the starting arm are shown at the left. The solenoid switch, S, can be closed by a push button when the starting arm is in the off position. When it is in any other position, pushing the button will open it. The series overload relay, M, which is set for a predetermined maximum current, open-circuits the solenoid, S, when it drops out, thus making it impossible to start the motor again until the controller arm has been returned to the off position.

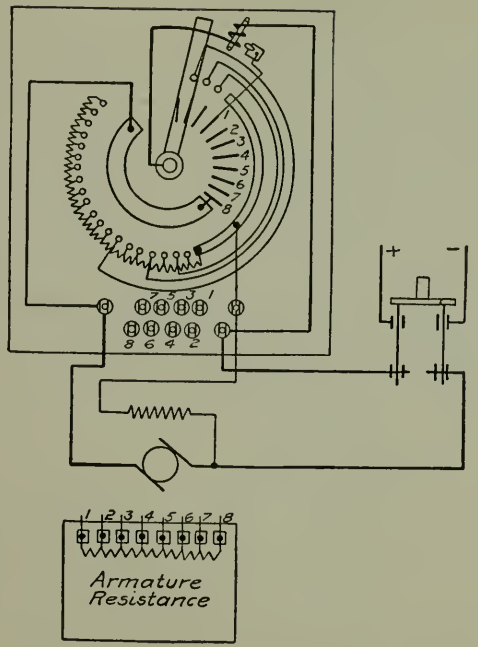


FIG. 268.—Connections for a non-reversing machine-tool controller. Like numbers on contacts, terminals and resistance taps are connected together. The field circuit resister is contained in the controller itself, while the armature rheostat is external to it.

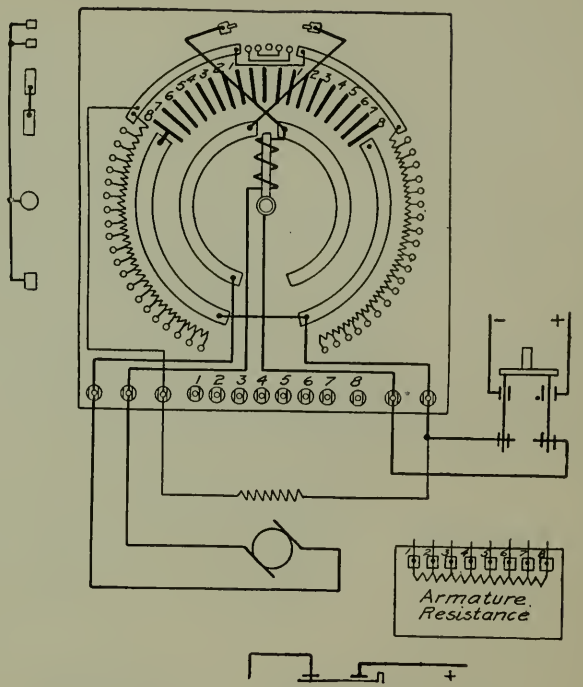


FIG. 269.—Full reverse machine-tool controller. Like numbers on the contacts, terminals and resistance taps are connected together. Connections of the controller arm are shown at the left. Two contacts at the extreme upper side of the controller are for the blow-out magnet. The field circuit resister is contained in the controller itself, while the armature rheostat is external to it.

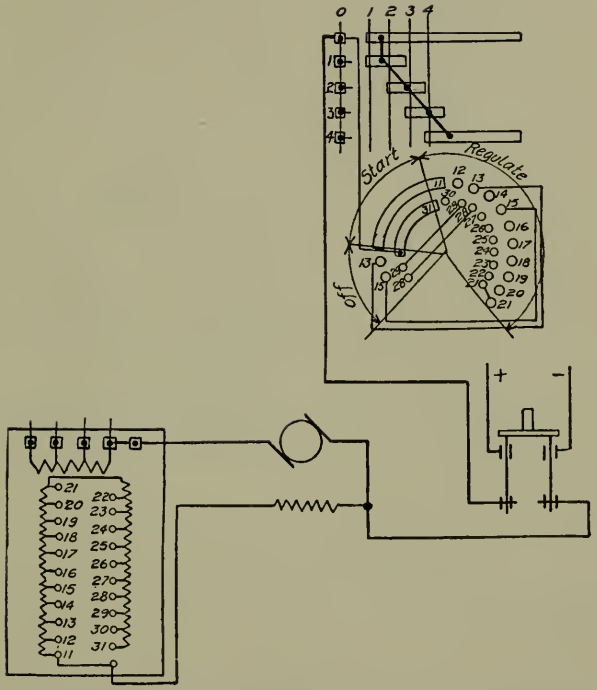


Fig. 270.—Connections for non-reversing machine-tool drum-type controller. Like numbers are connected together.

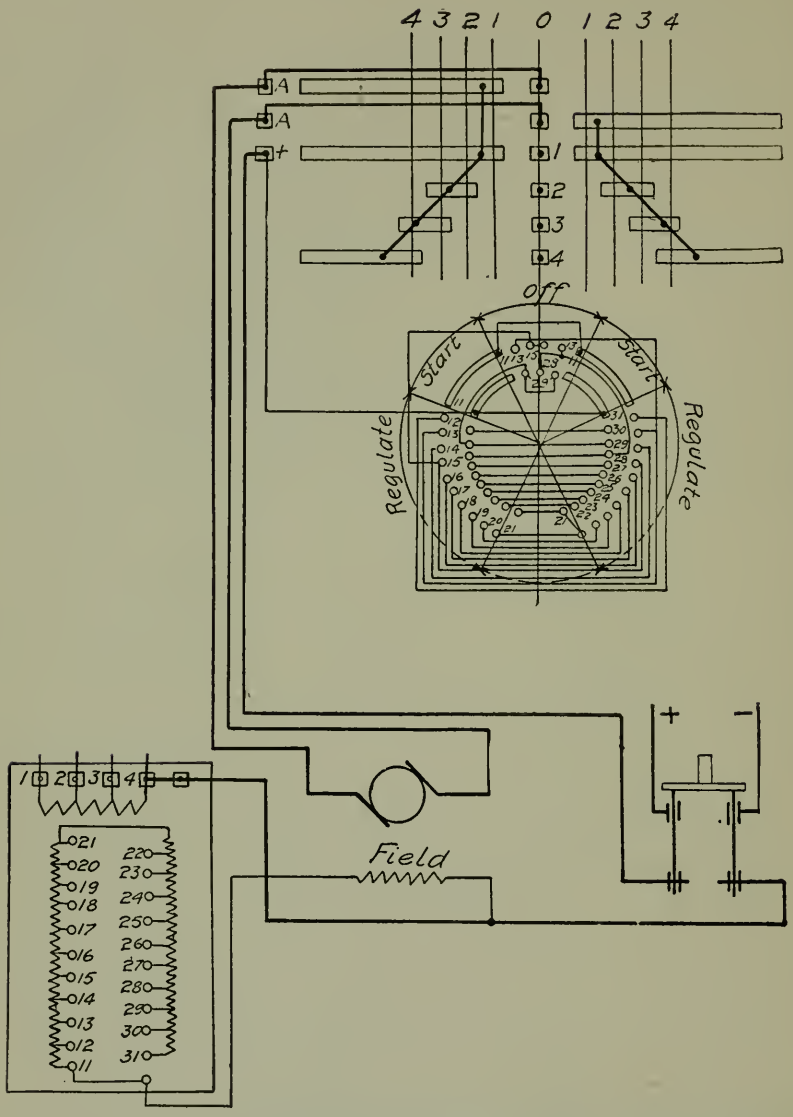


FIG. 271.—Connections for full reversing machine-tool drum-type controller. Like numbers are connected together.

SECTION XV

LIGHTNING ARRESTERS

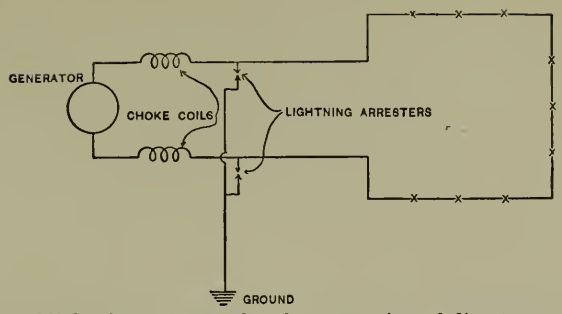


FIG. 272.—Location of lightning arresters for the protection of direct-current arc light circuits up to 6000 volts.

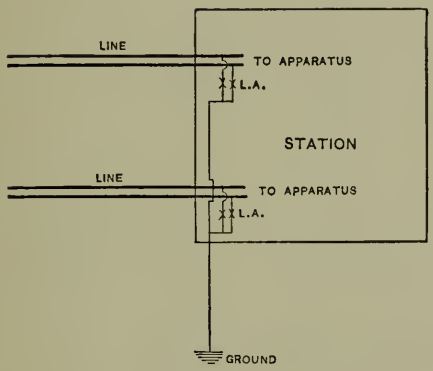


FIG. 273.

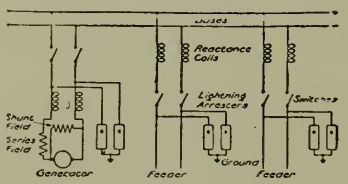


FIG. 274.

FIG. 273.—Location of lightning arresters for the protection of incandescent lighting circuits.

FIG. 274.—Connections of lightning arresters in a direct-current ungrounded system, up to 850 volts.

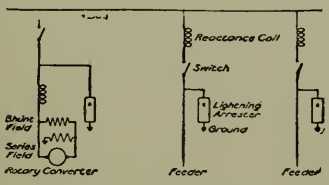


FIG. 275.

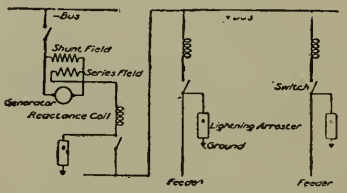


FIG. 276.

FIG. 275.—Connections of lightning arresters in a direct-current grounded return circuit up to 850 volts, machines closing on negative sides.

FIG. 276.—Connections of lightning arresters in a direct-current grounded return circuit up to 850 volts, machines closing on the positive sides.

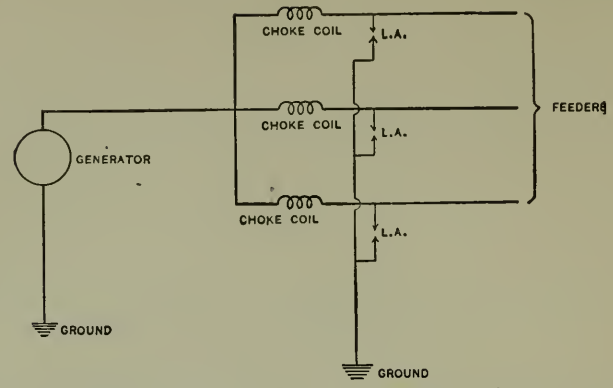


FIG. 277.—Location of lightning arresters for the protection of direct-current feeder circuits.

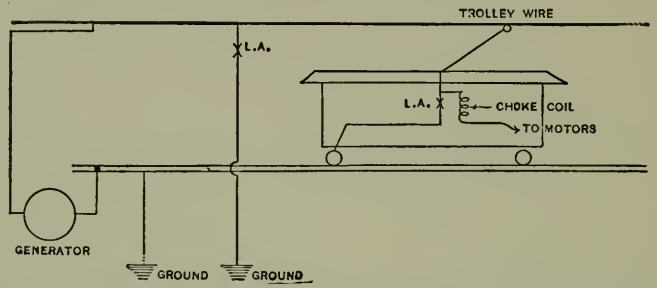


FIG. 278.—Location of lightning arresters for the protection of direct-current railway distribution circuits.

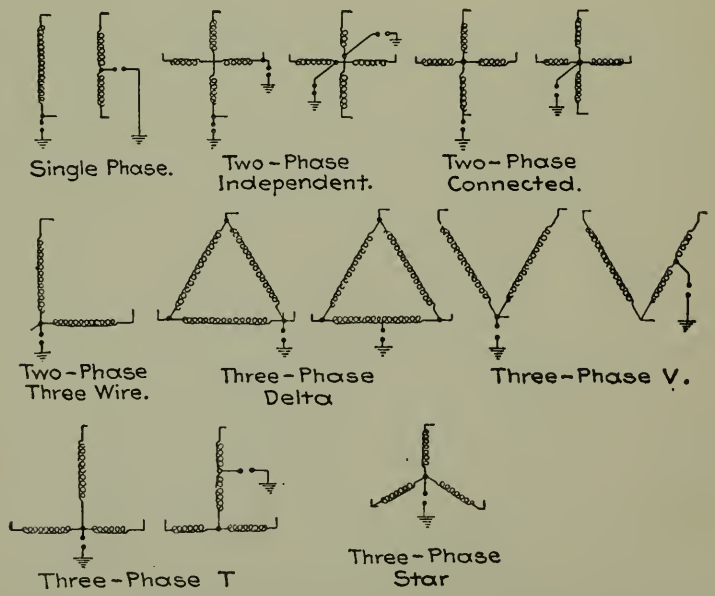


FIG. 279.—Location of spark-gap dischargers for various arrangements of transformers.

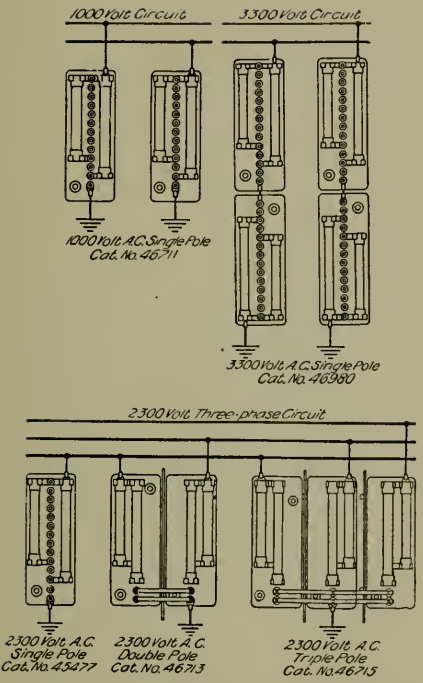


FIG. 280.

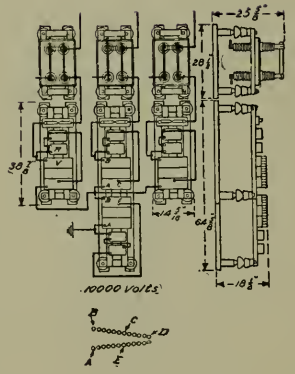


FIG. 281.

FIG. 280.—Connections of multi-gap arresters with shunt resistance.

FIG. 281.—Connections of multi-gap lightning arresters with shunt resistance with three-phase delta or star connected circuits with neutral ungrounded. Letters on the diagram denote the gap to which connection is made, and key being given on an enlarged V-gap at the bottom.

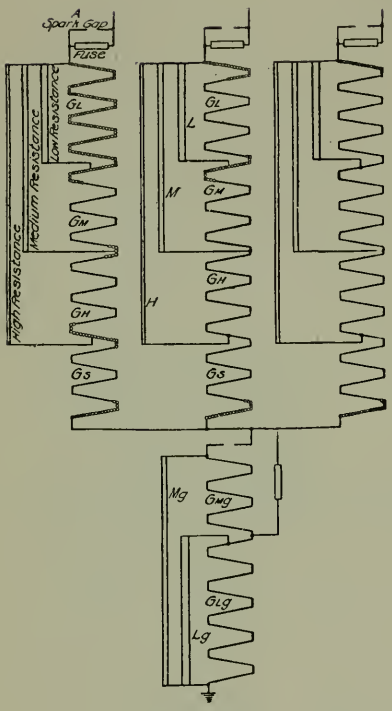


FIG. 282.

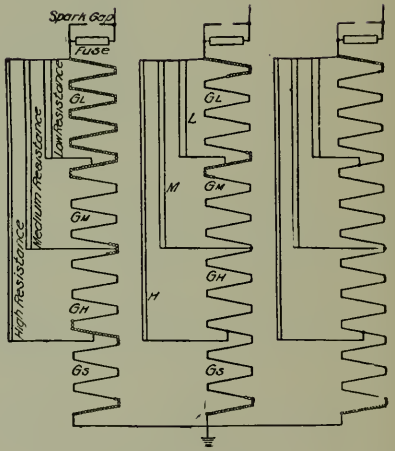
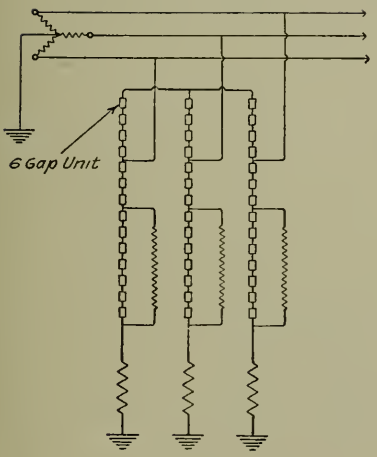


FIG. 283.

FIG. 282.—Multi-gap lightning arresters with graded shunt resistance connected for operation on a 3300-volt ungrounded star or delta system.

FIG. 283.—Multi-gap lightning arresters with graded shunt resistance for operation on star connected systems with grounded neutral.



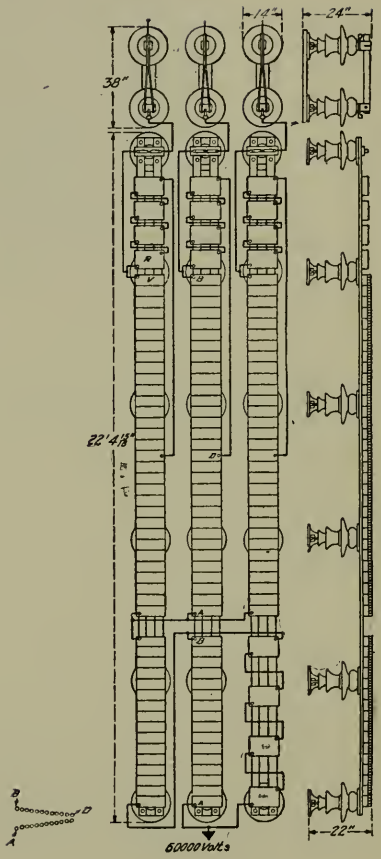


FIG. 284. FIG. 285.

FIG. 284.—Connection of low-equivalent lightning arrester to a 180,000-volt three-phase star connected circuit with grounded neutral.

FIG. 285.—Connections of multi-gap lightning arresters with shunt resistance with three-phase delta or star connected circuits with neutral ungrounded. Letters on the diagram denote the gap to which connection is made, and key being given on an enlarged V-gap at the bottom.

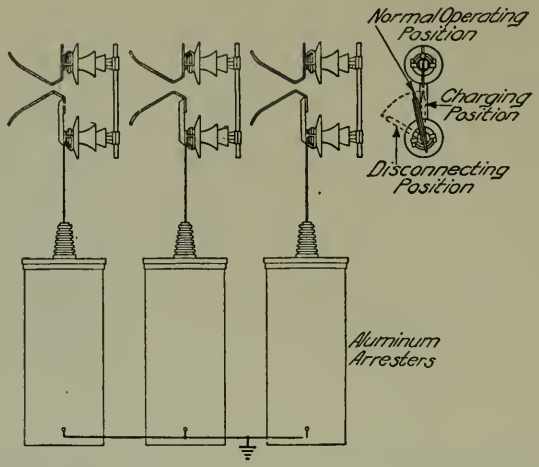


FIG. 286.—Connection of an aluminum lightning arrester to a grounded neutral system from 30,000 to 100,000 volts. The horn gaps are placed horizontally, not as shown.

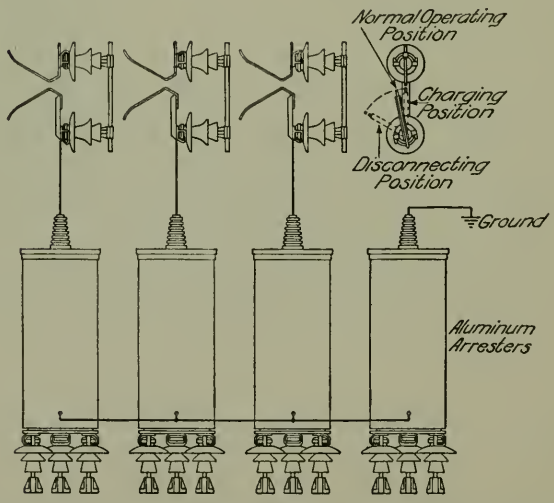


FIG. 287.—Connection of aluminum lightning arresters to a delta or ungrounded system, from 30,000 to 100,000 volts. The horn gaps are placed horizontally, not as shown.

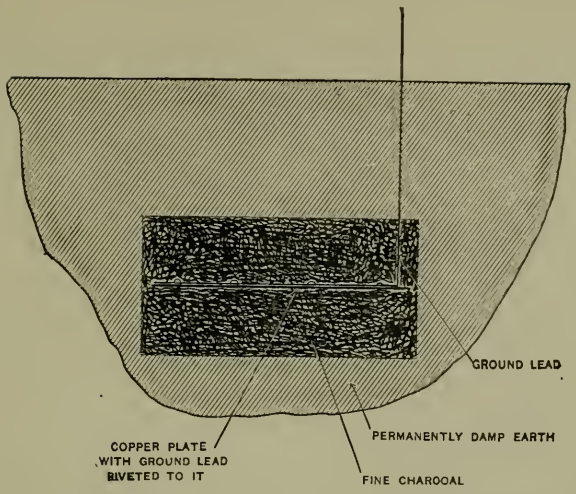


FIG. 288.—Standard form of ground connection for lightning arresters.

SECTION XVI

MEASURING INSTRUMENTS

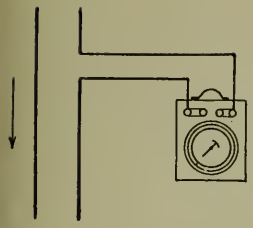


FIG. 289.

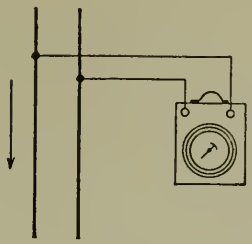


FIG. 290.

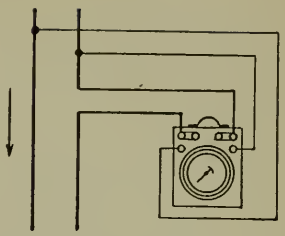


FIG. 291.

FIG. 289.—Ammeter connected in series with the circuit, either direct or alternating current.
FIG. 290.—Voltmeter connected directly across the line, either direct or alternating e.m.f.
FIG. 291.—Connections for a wattmeter, either direct-current or alternating single-phase current.

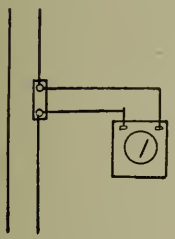


FIG. 292.

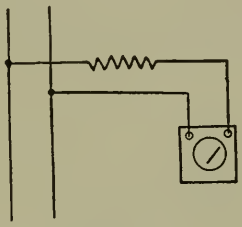


FIG. 293.

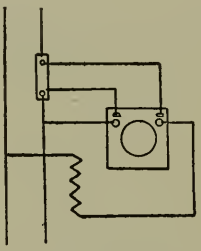


FIG. 294.

FIG. 292.—Direct-current ammeter used with shunt.
FIG. 293.—Direct-current voltmeter used with multiplier. The true e.m.f. is obtained by multiplying the reading of the voltmeter by the sum of the resistance of the multiplier and that of the voltmeter, divided by the resistance of the voltmeter
FIG. 294.—Direct-current wattmeter using multiplier with the shunt coil in shunt with the series coil.

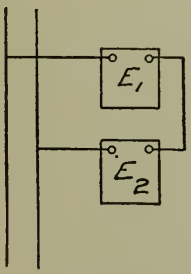


FIG. 295.

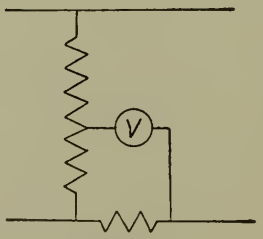


FIG. 296.

FIG. 295.—Two voltmeters in series for measuring voltages beyond the range of either one of the instruments. $E = E_1 + E_2$. The maximum voltage which can be measured with two voltmeters in series depends upon the ratio of the resistances. If $R_1 = 100{,}000$ ohms and the range is 500 volts, and $R_2 = 170{,}000$ ohms and the range is 600 volts. The maximum volts which they can measure when connected in series is:

Sum of resistances $\times$ larger range $\div$ larger resistance

$100{,}000 + 170{,}000 \times 600 \div 170{,}000 = 950$ volts

FIG. 296.—Connections of a compensated voltmeter for reading voltage at any point on a direct-current line. The scale of the voltmeter is so constructed that it reads full voltage when the line is opened and zero when it is short-circuited.

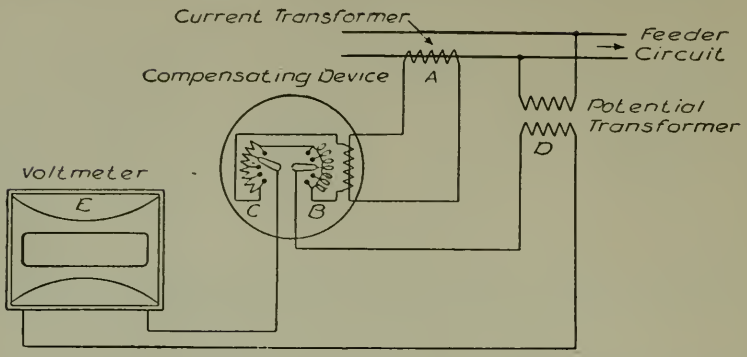


Fig. 297.—Connections for a compensated voltmeter adjusted to indicate the voltage at any desired point along an alternating current line. A is a series transformer, D a shunt transformer, B a reactance coil and C a resistance coil. C and B are adjusted to give a resistance and reactance proportional to that of the line between the point where the voltmeter is connected and the point where it is desired to indicate the voltage.

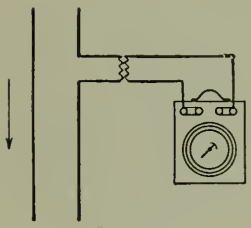


Fig. 298.

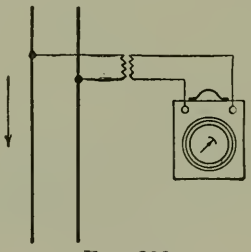


Fig. 299.

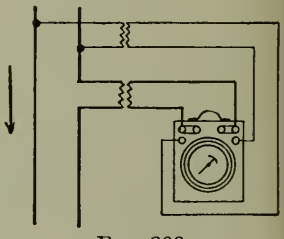


Fig. 300.

Fig. 298.—Ammeter connected to a series transformer.
Fig. 299.—Voltmeter connected to a shunt transformer.
Fig. 300.—Single-phase wattmeter connected with series and shunt instrument transformers.

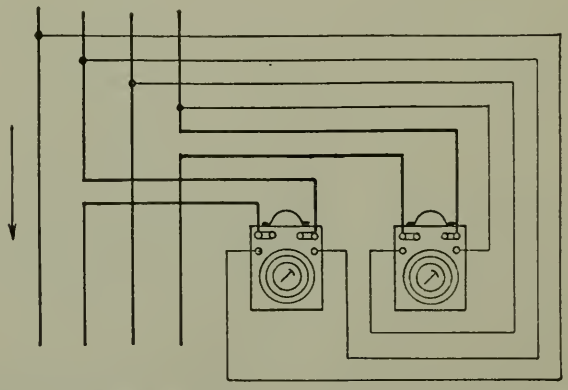


Fig. 301.—Two single-phase wattmeters connected for measuring two-phase power.

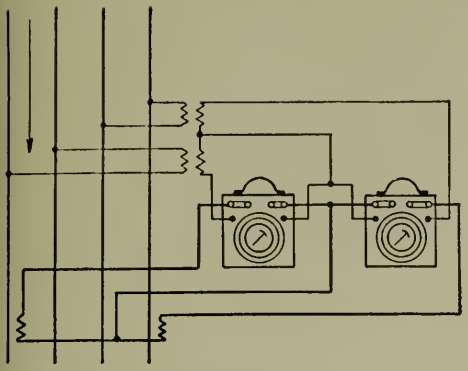


FIG. 302.

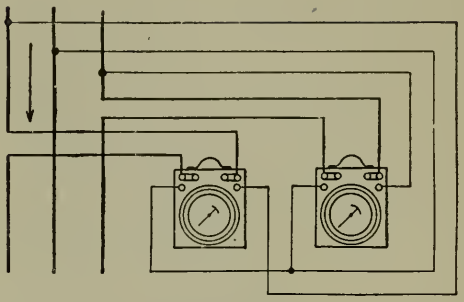


FIG. 303.

FIG. 302.—Two single-phase wattmeters connected to a two-phase circuit with instrument transformers.

FIG. 303.—Two single-phase wattmeters connected to measure three-phase power.

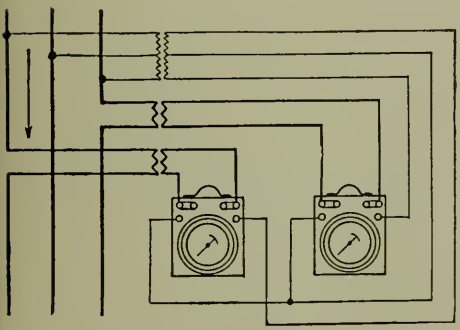


FIG. 304.

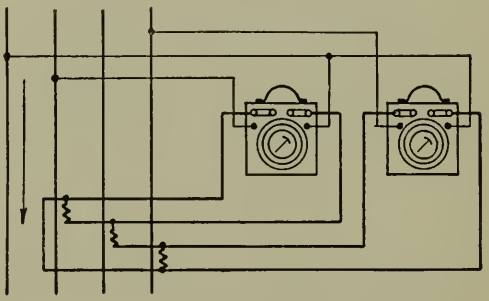


FIG. 305.

FIG. 304.—Two single-phase wattmeters connected to a three-phase circuit with instrument transformers.

FIG. 305.—Two single-phase wattmeters connected to a four-wire three-phase circuit using series transformers. Series transformers are always used for this connection.

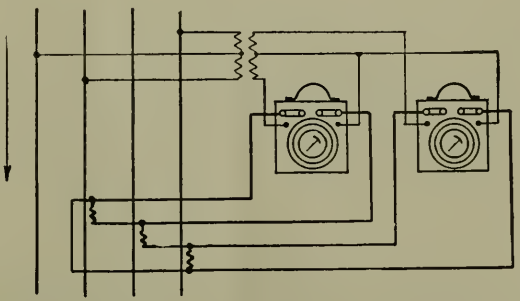


FIG. 306.—Two single-phase wattmeters connected to a four-wire three-wire circuit using both shunt and series transformers.

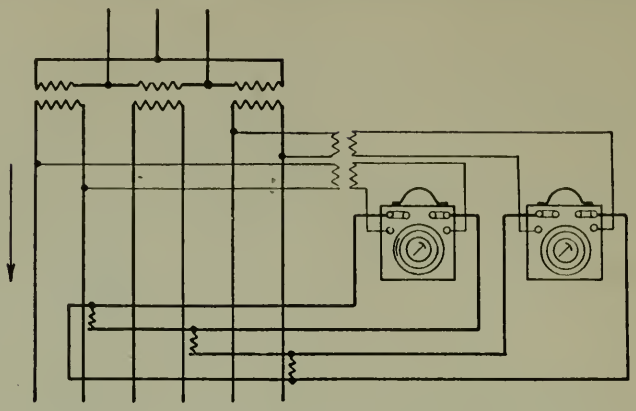


FIG. 307.—Two single-phase wattmeters connected to measure power in a six-phase circuit.

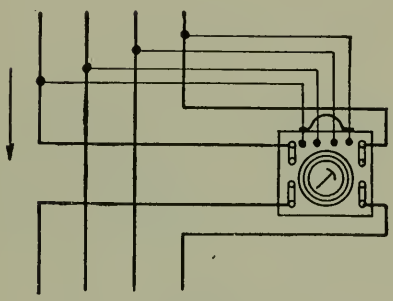


FIG. 308.

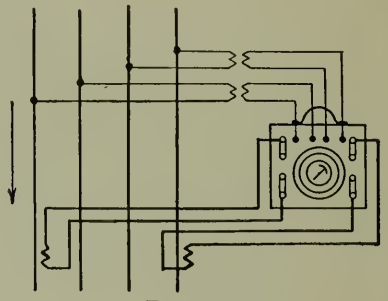


FIG. 309.

FIG. 308.—Polyphase wattmeter connected to a four-wire two-phase circuit.
FIG. 309.—Polyphase wattmeter connected to a four-wire two-phase circuit with instrument transformers.

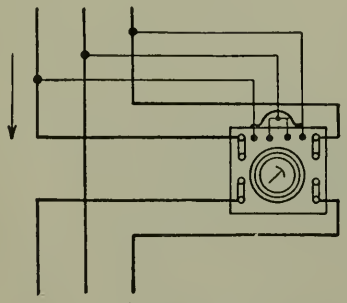


FIG. 310.

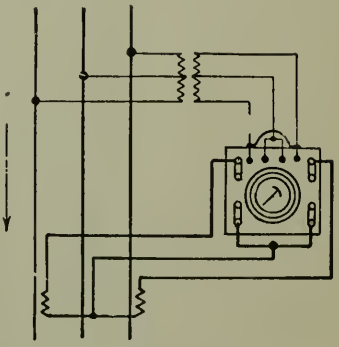


FIG. 311.

FIG. 310.—Polyphase wattmeter connected to measure three-phase power.
FIG. 311.—Polyphase wattmeter connected to a three-phase circuit with instrument transformers.

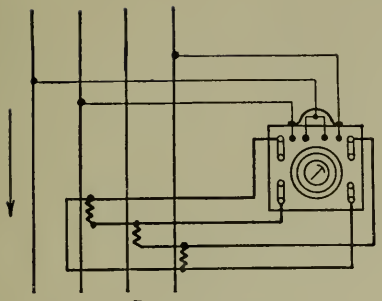


FIG. 312.

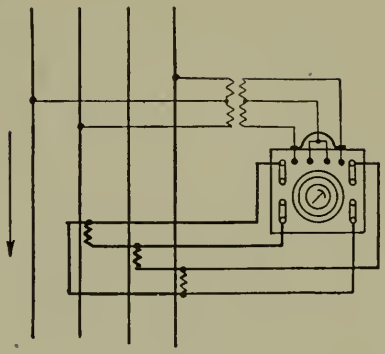


FIG. 313.

FIG. 312.—Polyphase wattmeter connected to a four-wire three-phase system. Series transformers always used with this connection.

FIG. 313.—Polyphase wattmeter connected to a four-wire three-phase circuit, using both shunt and series transformers.

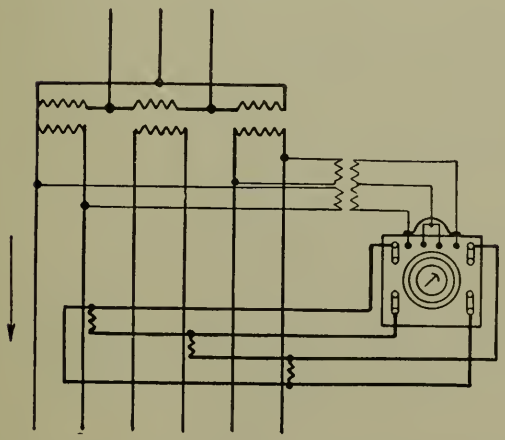


FIG. 314.

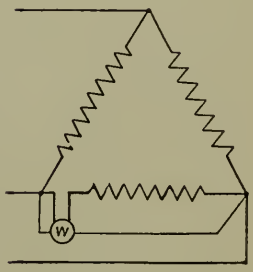


FIG. 315.

FIG. 314.—Polyphase wattmeter connected to measure power in a six-phase circuit. Three series transformers always necessary.

FIG. 315.—Single-phase wattmeter connected to measure power in one leg of a delta connected load. Total power consumed equals three times the reading.

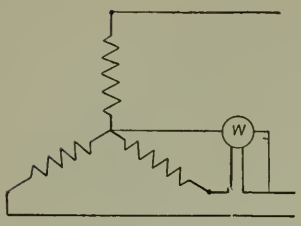


FIG. 316.

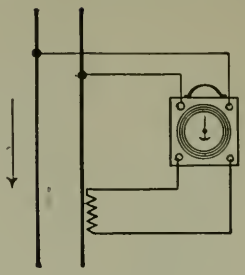


FIG. 317.

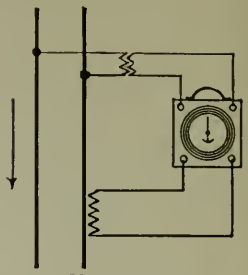


FIG. 318.

FIG. 316.—Single-phase wattmeter connected to read the power consumed in one leg of a star connected load. The total power equals three times the reading.

FIG. 317.—Connections of a power-factor meter for a single-phase circuit.

FIG. 318.—Power-factor meter connected to a single-phase circuit with instrument transformers.

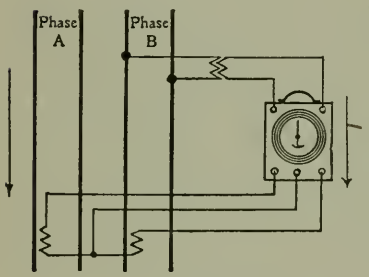


FIG. 319.

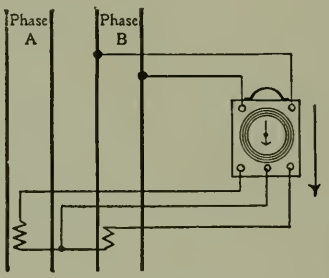


FIG. 320.

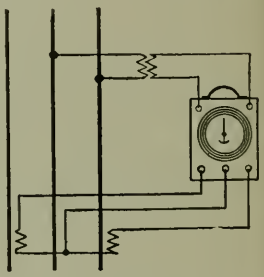


FIG. 321.

FIG. 319.—Power-factor meter connected to a two-phase circuit with instrument transformers.

FIG. 320.—Power-factor meter connected to a two-phase circuit.

FIG. 321.—Power-factor meter connected to a three-phase circuit.

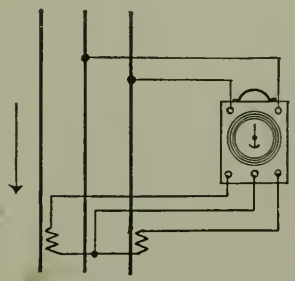


FIG. 322.—Power-factor meter connected to a three-phase circuit.

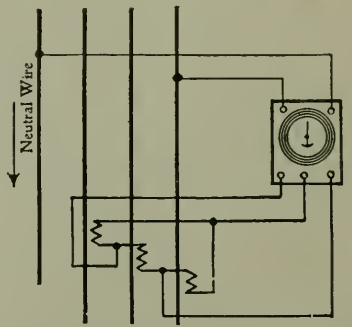


FIG. 323.—Power-factor meter connected to a four-wire three-phase circuit.

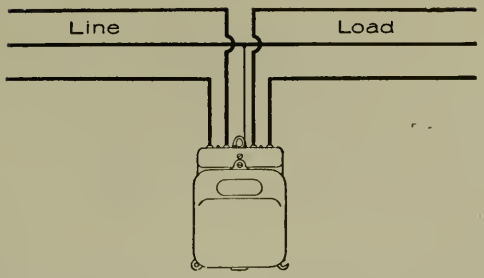


FIG. 324.—Connections for a three-phase watt-hour meter.

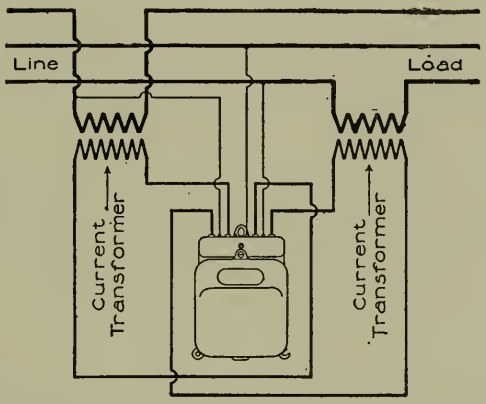


FIG. 325.—Connections for three-phase watt-hour meter using three-series transformers.

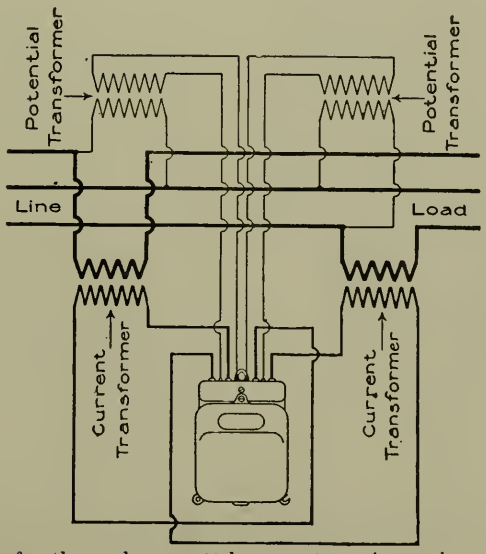


FIG. 326.—Connections for three-phase watt-hour meter using series and shunt transformers.

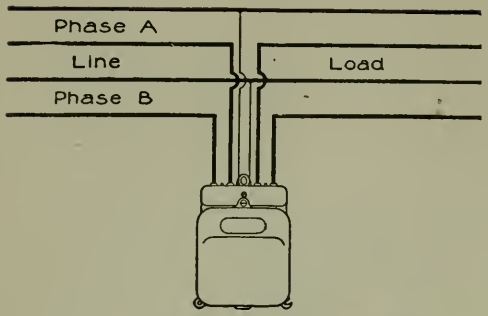


FIG. 327.—Connections for a two-phase watt-hour meter.

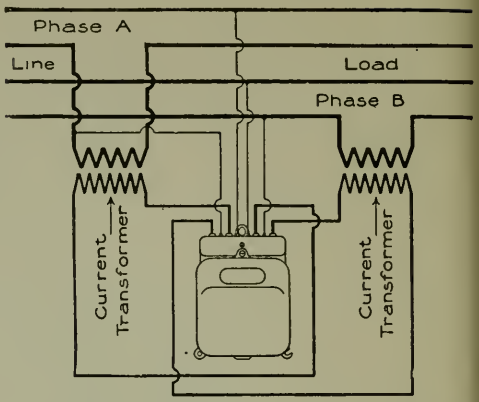


FIG. 328.—Connections for a two-phase watt-hour meter using series transformers.

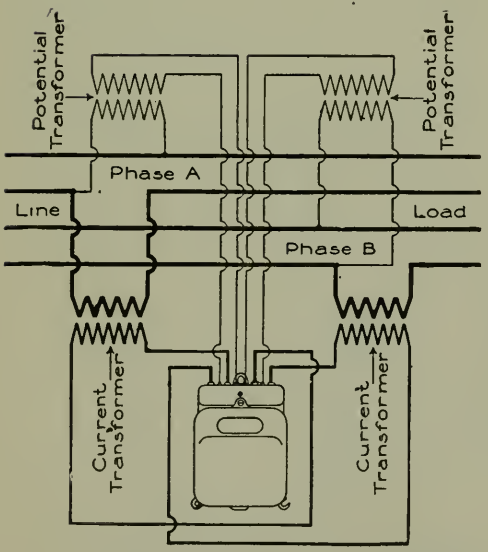


FIG. 329.—Connections for two-phase watt-hour meter using series and shunt transformers.

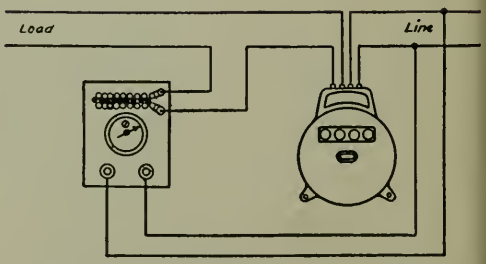


FIG. 330.—Connections for testing a watt-hour meter with a precision watt-hour meter.

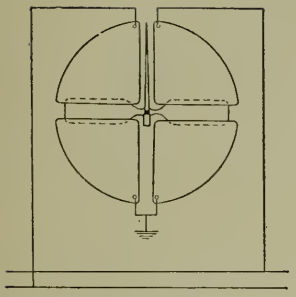


Fig. 331.

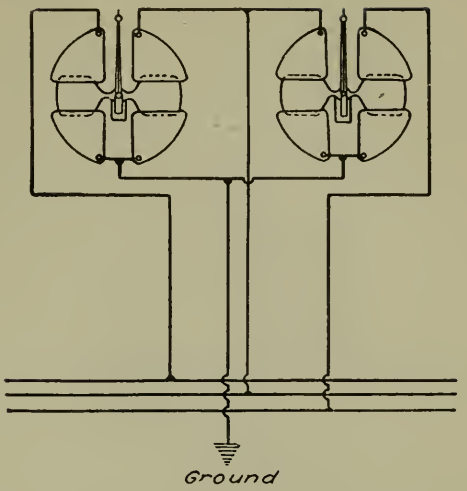


Fig. 332.

Fig. 331.—Connections for two-wire static ground detector. The principle is the same as that of the quadrant electrometer. As long as the e.m.f. between the ground and each line is the same, the hand remains in the upright position, pull on the vanes being balanced. In case one side becomes grounded, the balance becomes upset and the pointer takes another position, indicating the line on which the ground exists.

Fig. 332.—The two-wire ground detectors connected to a three-wire system.

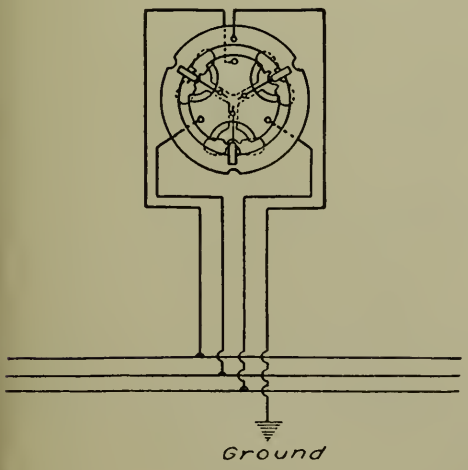


Fig. 333.

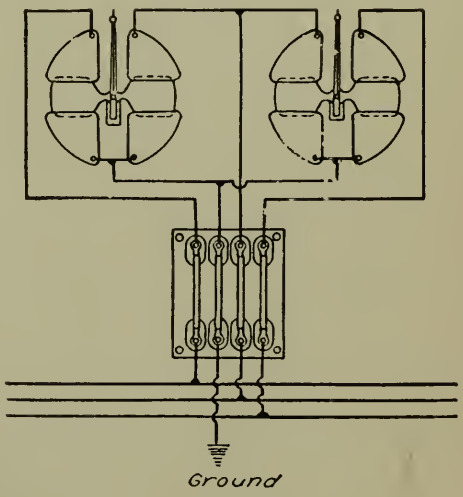


Fig. 334.

Fig. 333.—A three-wire or three-phase ground detector connected to a three-wire system.

Fig. 334.—Static ground detectors connected to a three-wire line through protective resistances.

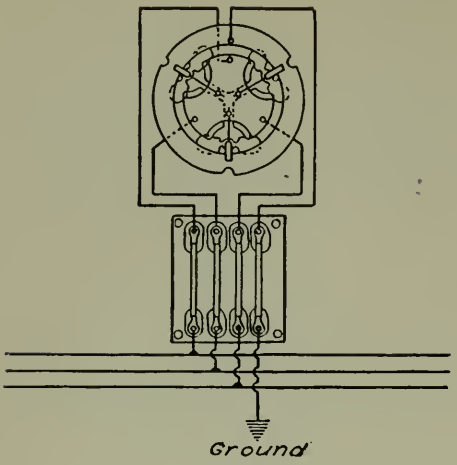


FIG. 335.

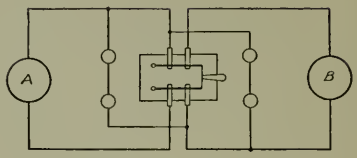


FIG. 336.

FIG. 335.—Three-wire or three-phase ground detector connected to a three-wire line through a protective resistance.

FIG. 336.—Connections of synchronizing lamps for synchronizing light. A and B are the machines to be synchronized.

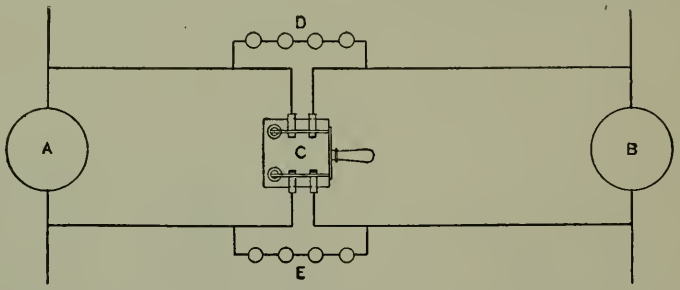


FIG. 337.—Connections of synchronizing lamps for synchronizing dark.

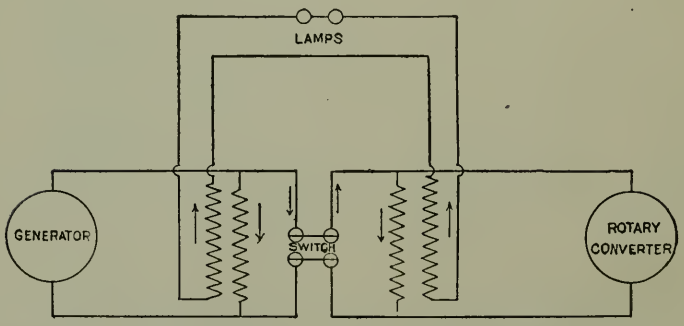


FIG. 338.—Connections of synchronizing lamps for synchronizing dark, shunt transformers for lowering the voltage.

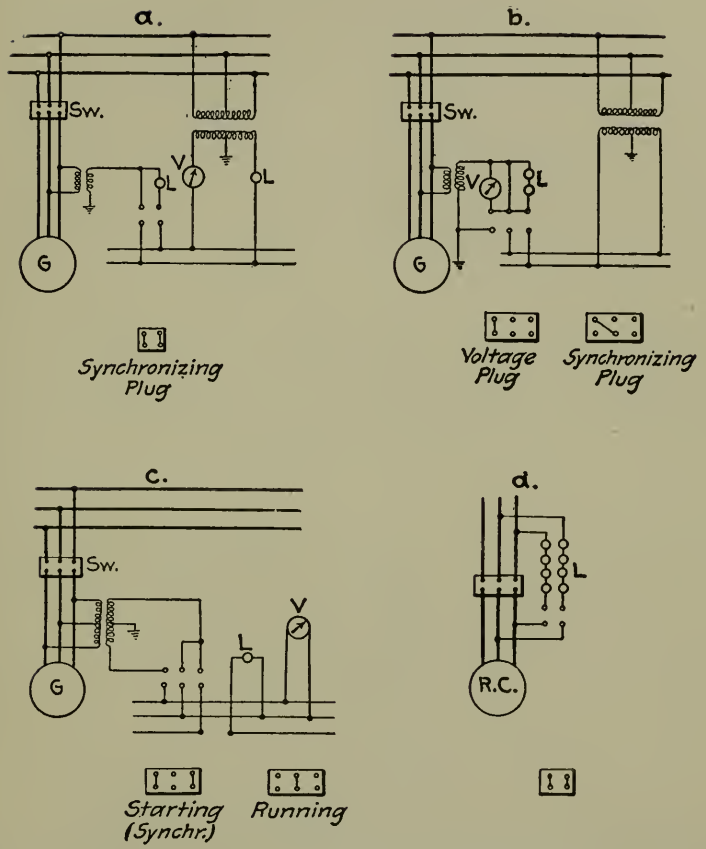


FIG. 339.—Connections of synchronizing lamps with plug switches, synchronizing dark.

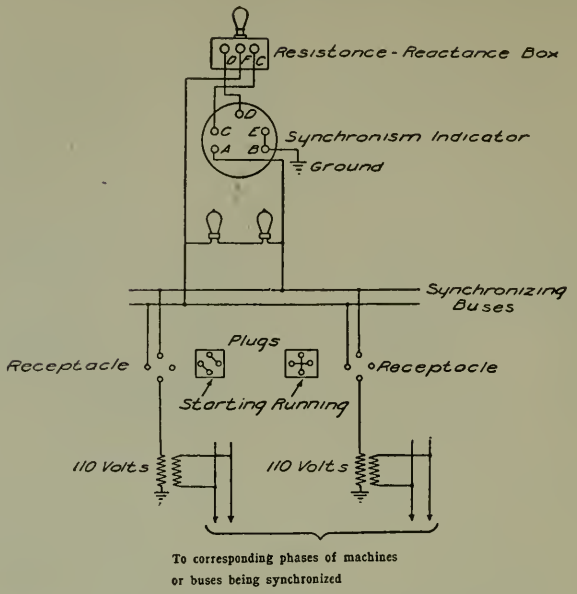


FIG. 340.—Connections for synchronism indicator and lamps for synchronizing dark. Shunt transformer with secondaries grounded.

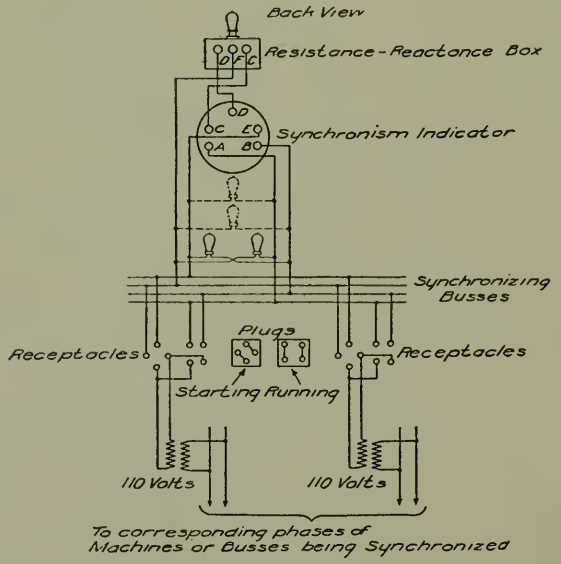


FIG. 341.—Connections for synchronism indicator and lamps for synchronizing dark. Shunt transformer with secondaries grounded.

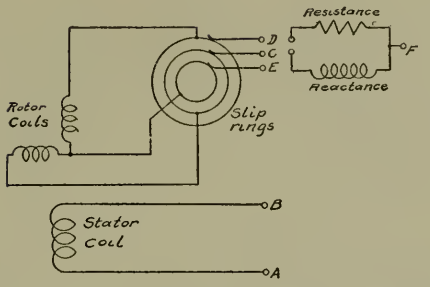


FIG. 342.—Internal connections of synchronism indicator. Letters refer to terminals shown in Figs. 340 and 341.

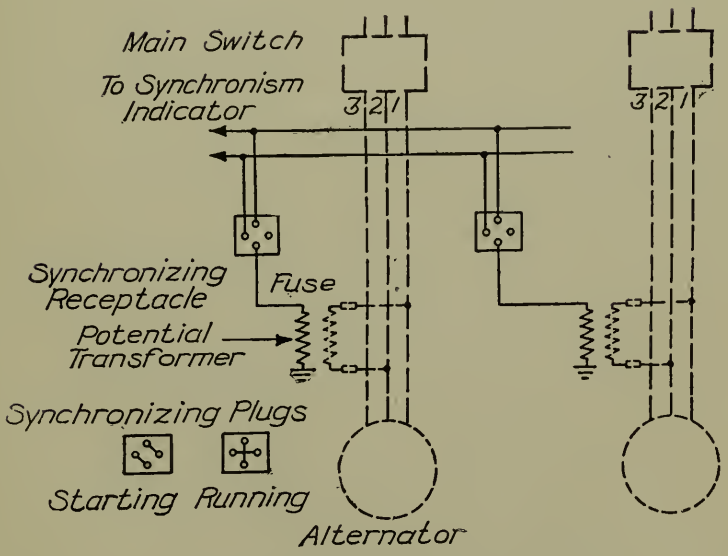


FIG. 343.—Connections of plug switches for use with synchronism indicator. Secondaries of shunt transformers grounded.

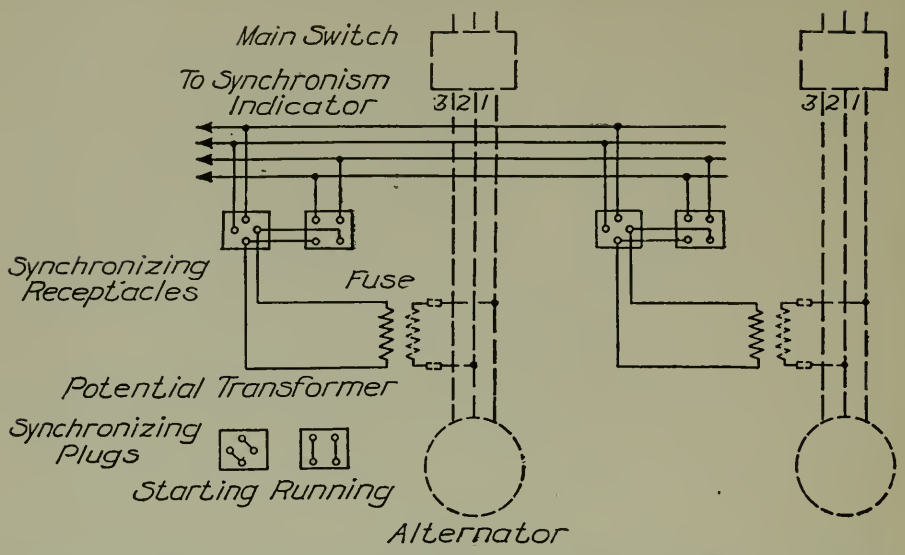


Fig. 344.—Connections of plug switches for use of synchronism indicator. Secondaries of shunt transformers not grounded.

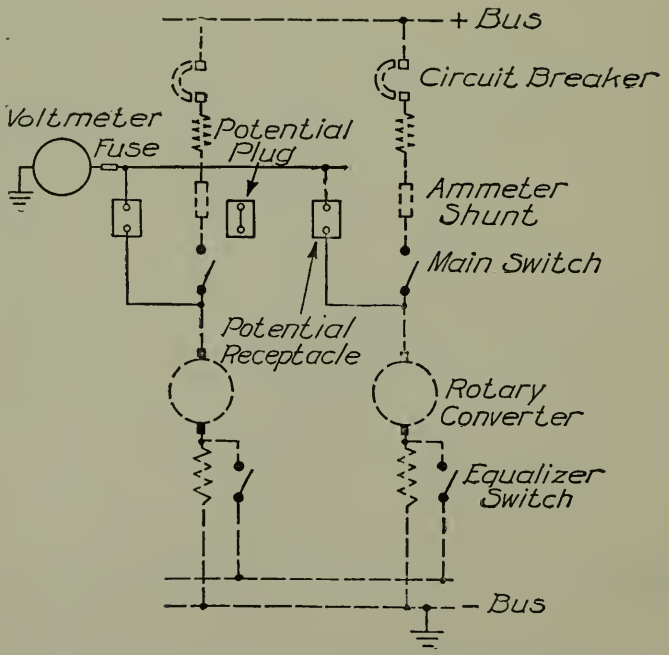


Fig. 345.—Connections of plug switches for use with voltmeter on direct-current generator or synchronous converter panels. Ground return system.

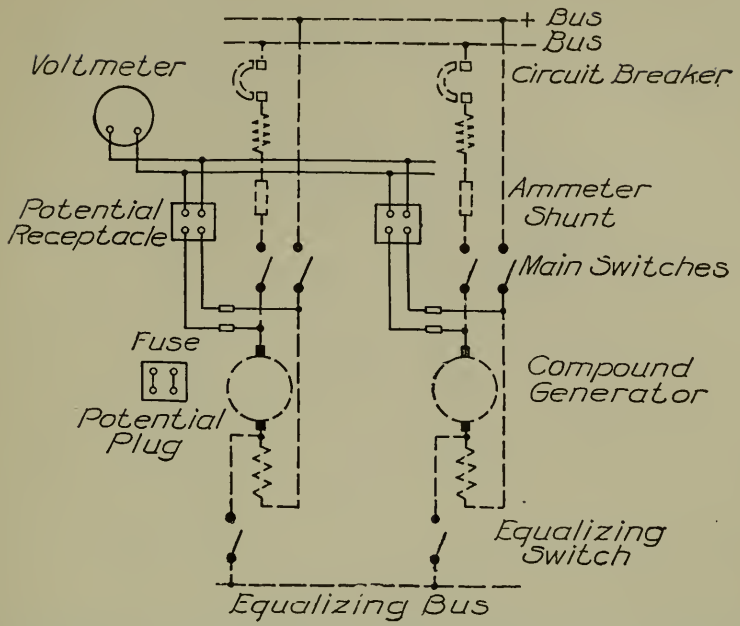


FIG. 346.—Connections of plug switches for use with voltmeter on direct-current generator or synchronous converter panels. Metallic return system, two-wire.

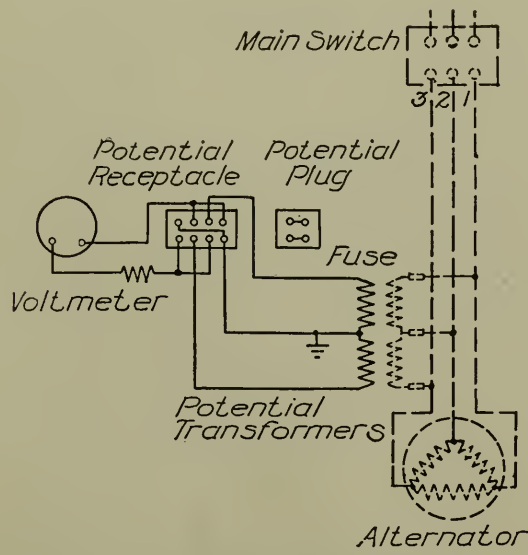


FIG. 347.—Connections of plug switches for reading voltage of three-phase generator.

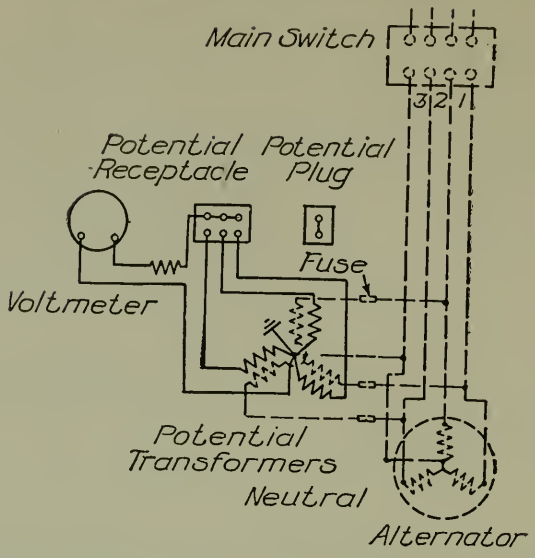


FIG. 348.—Connections of plug switches for reading voltage of three-phase four-wire generator.

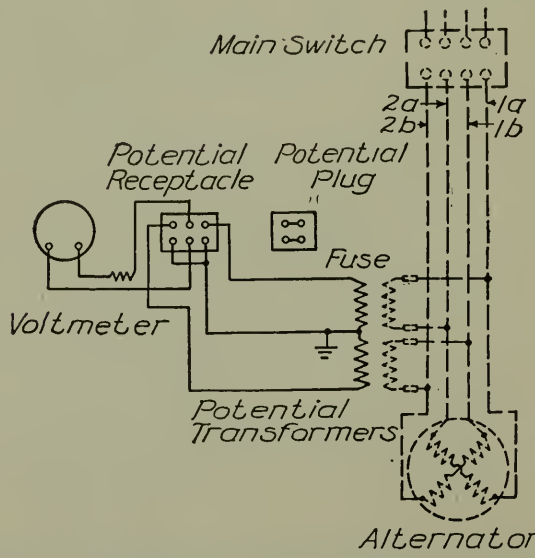


FIG. 349.—Connections of plug switches for reading voltage of two-phase four-wire generator. Phases not interconnected.

SECTION XVII

REMOTE CONTROLLED AND AUTOMATIC SWITCHES AND CIRCUIT BREAKERS

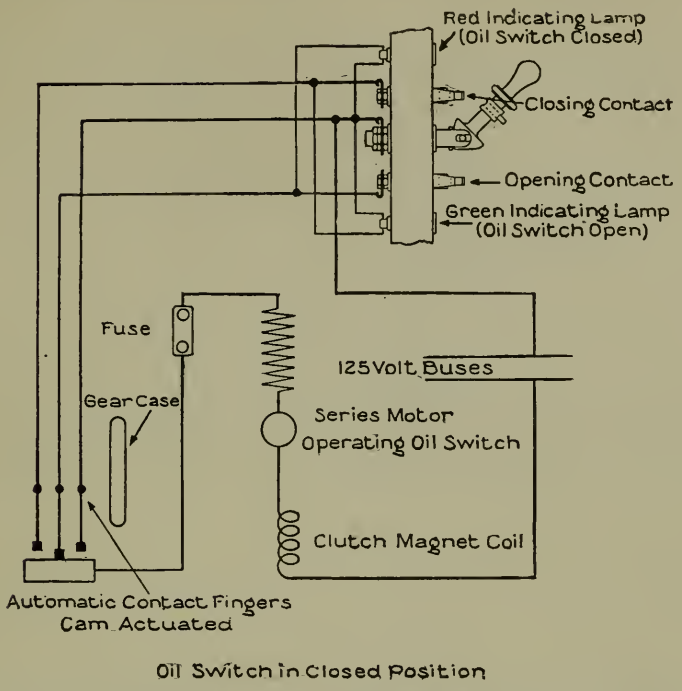


FIG. 350.—Connections for the remote electrical control of oil switches.

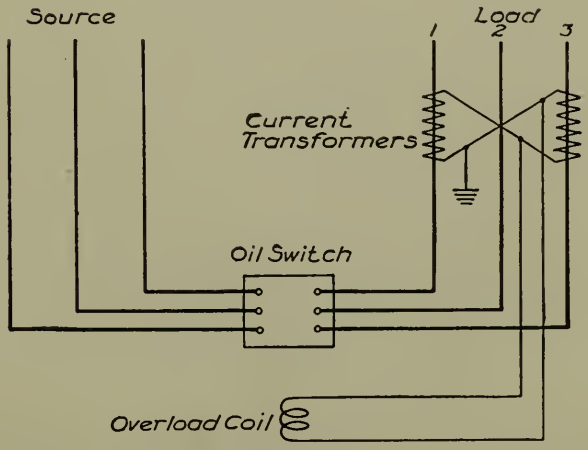


FIG. 351.—Connections for automatic oil switch mounted on panel.

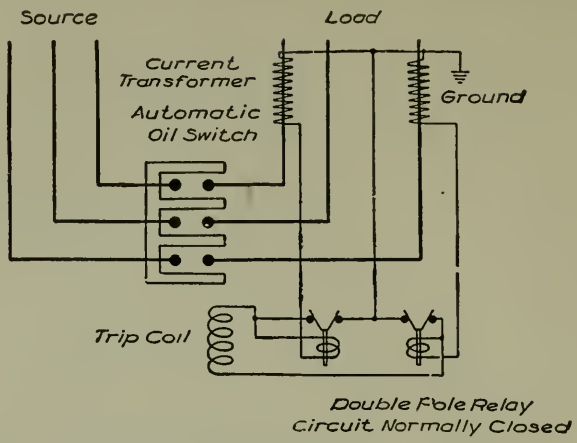


Fig. 352.—Connections for remote control of an automatic oil switch.

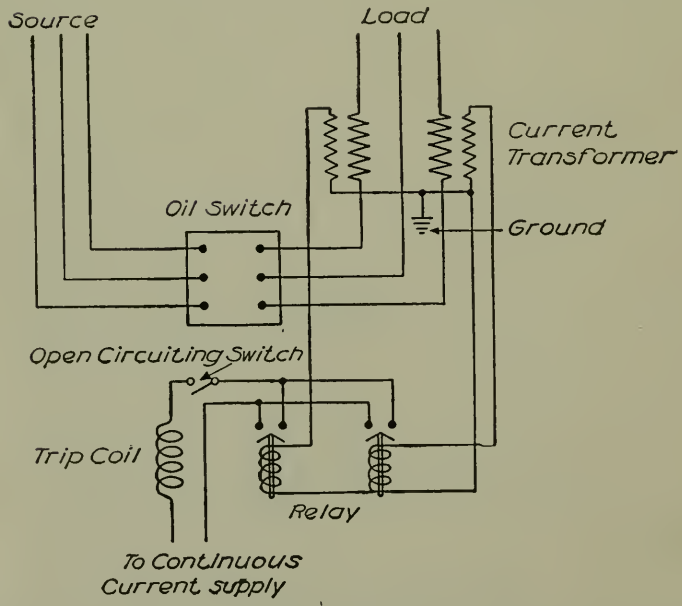


Fig. 353.—Connections for remote control of an automatic oil switch using direct current in the trip coil circuit.

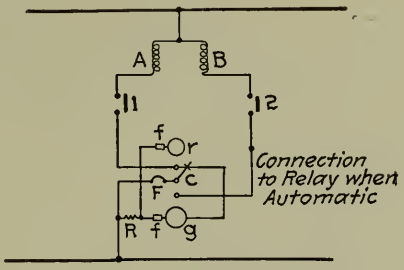


FIG. 354.—Connections for a solenoid-operated oil switch control with signal lamps. A is the closing and B the opening solenoid. Auxiliary switch, S, is used automatically to cut out of circuit the coil last operated and insert the other so that it will respond when the control switch, C, is thrown over. The operation of S is accomplished by the solenoids themselves. Signal lamps g and r indicate open and closed circuits respectively.

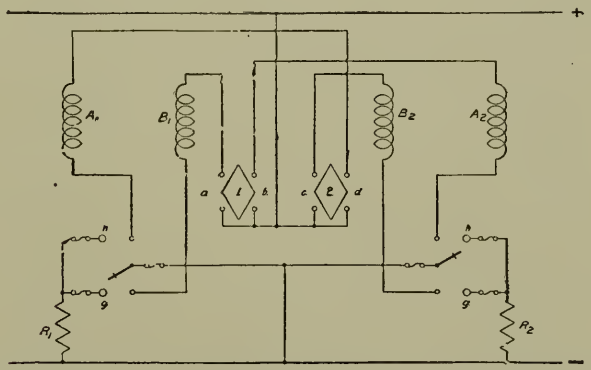


FIG. 355.—Connections for interlocking two solenoid-operated switches. Solenoids A_1 and A_2 close, and B_1 and B_2 open their respective oil switches. The operation of the opening coil A moves the auxiliary switch S to the left (*a* side), and the operation of the closing coil B moves it to the right (*b* side). The connections are such that both switches cannot be closed at the same time. When the closing coils B are operated, they automatically cut themselves out of the circuit by means of the auxiliary switches S.

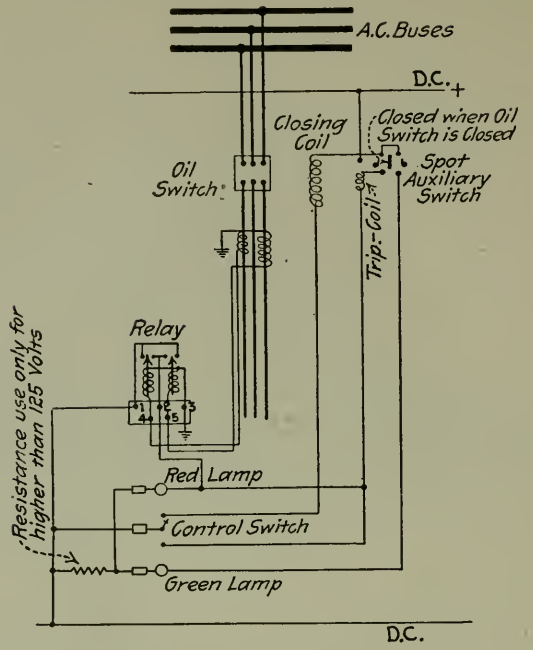


FIG. 356.—Controlling circuit for a solenoid-operated oil switch.

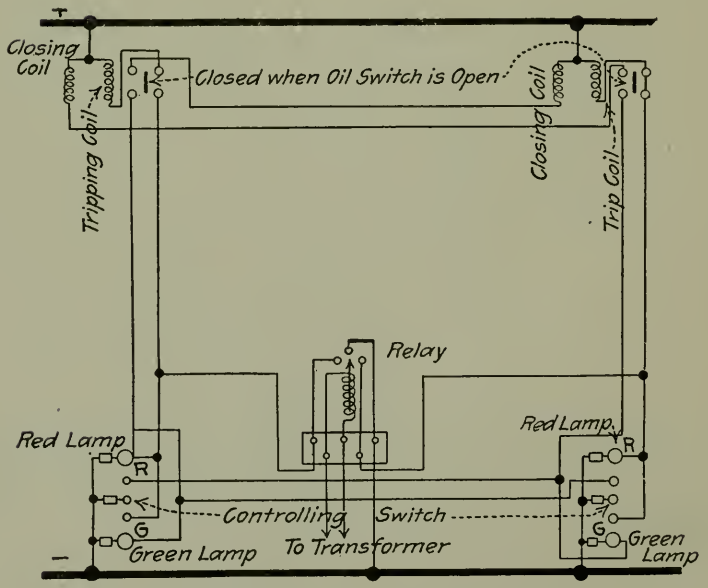


FIG. 357.—Connections of an interlocking system for two solenoid-operated oil switches arranged to be tripped by an automatic relay.

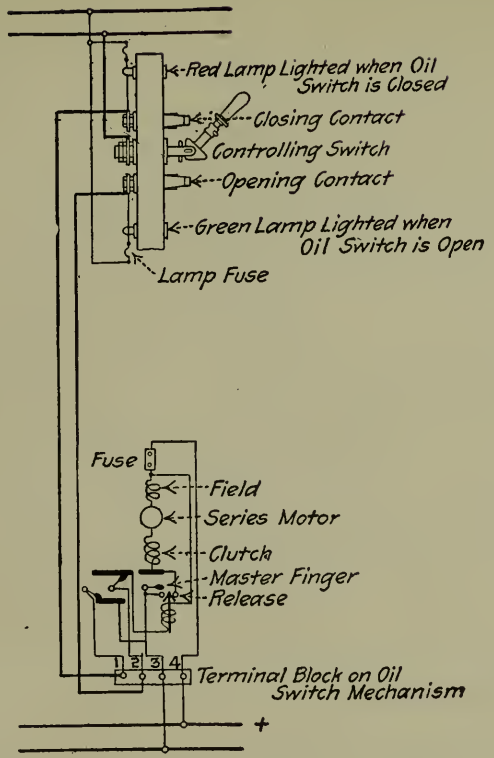


FIG. 358.—Electric control connections for a spring-operated oil switch. Springs are wound up by a series motor after each operation. Finger *a* is down when the oil switch is open, and up when it is closed; while finger *b* is up when the oil switch is open, and down when it is closed.

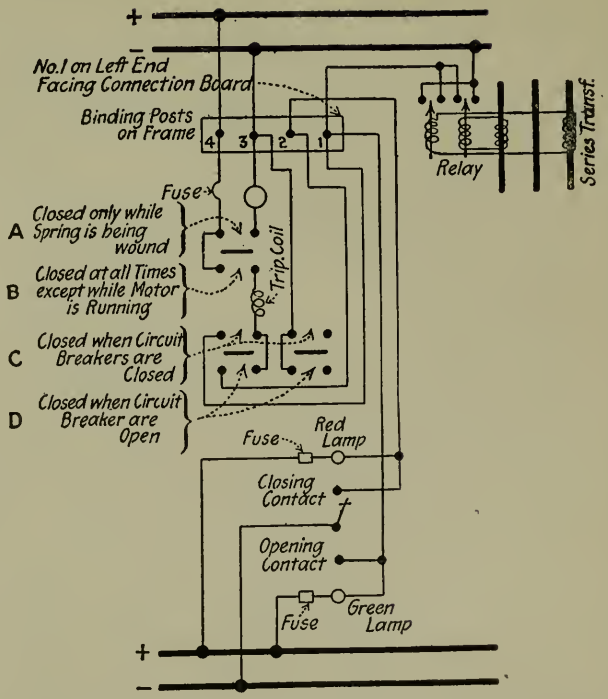


FIG. 359.—Internal connections of a motor-operated switch mechanism.

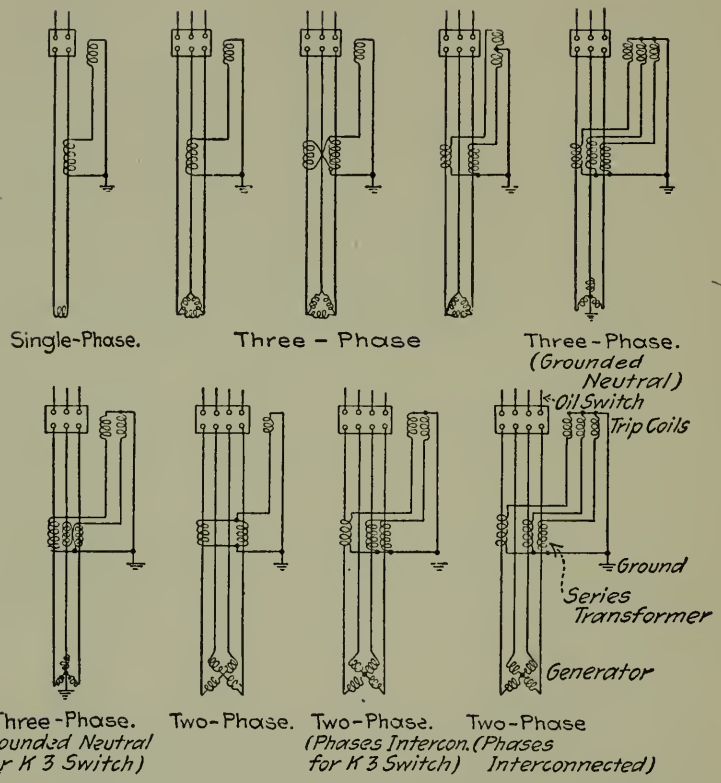
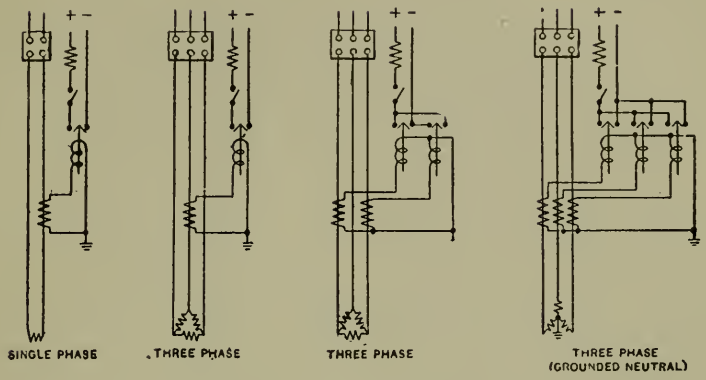


FIG. 360.—Connections for oil switches with trip coils operating on an alternating current circuit excited by series transformers.



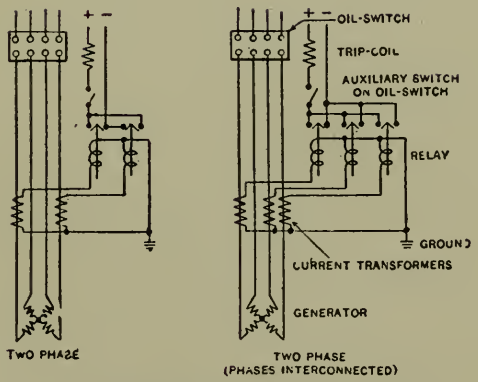


FIG. 361.—Connections for oil switches with trip coils operating on a direct-current circuit, using circuit-closing relays.

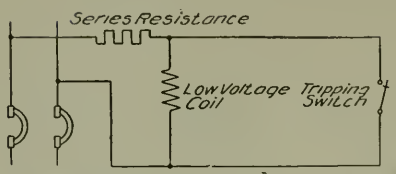


FIG. 362.—Connection of low-voltage trip. Tripping switch normally open.

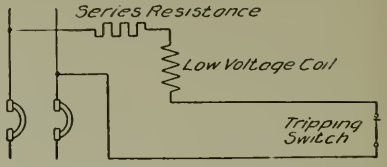


FIG. 363.—Connection of low-voltage trip. Tripping switch normally closed.

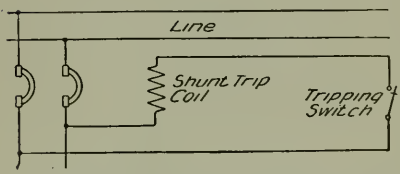


FIG. 364.—Connection of shunt trip. Tripping circuit dead after operation of the breaker.

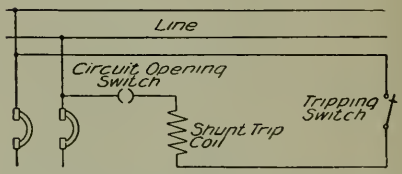


FIG. 365.—Connection of shunt trip. Tripping circuit rendered dead by plug switch.

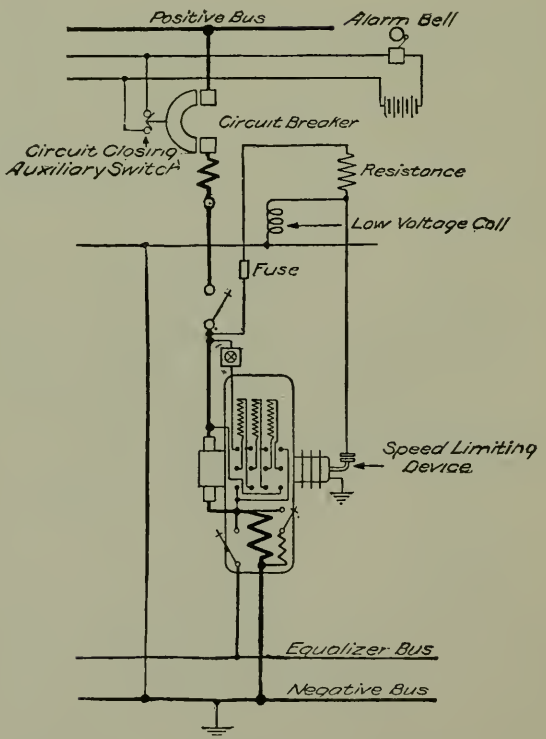


FIG. 366.—Connection of low-voltage trip coil to speed limiting device used on a synchronous converter.

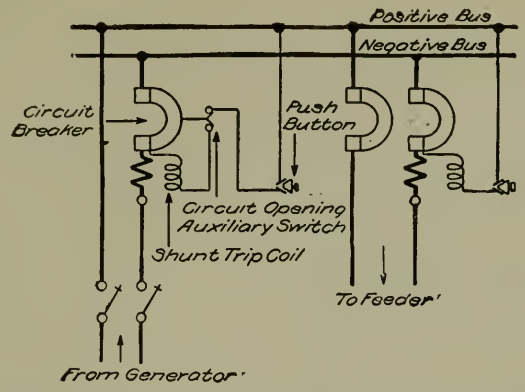


FIG. 367.—Connection of shunt trip coil with or without circuit-opening auxiliary switch.

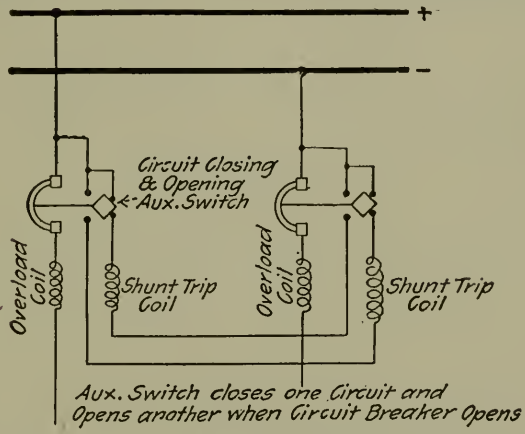


FIG. 368.—Connections of system for interlocking two circuit-breakers by means of shunt trips and auxiliary switches.

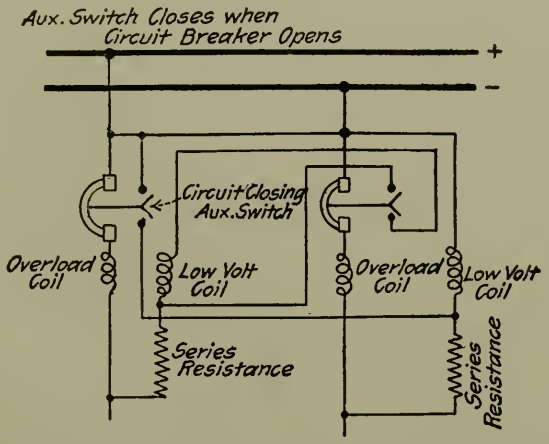


FIG. 369.—Connections of system for interlocking two circuit-breakers by means of low-voltage trips and auxiliary switches.

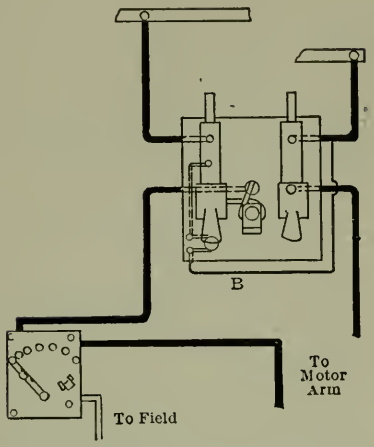


FIG. 370.—Connections of an overload and no-voltage release circuit-breaker.

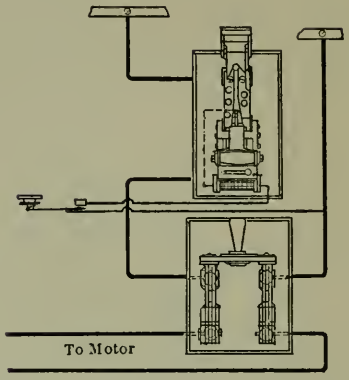


FIG. 371.—Connections of an auxiliary shunt trip for a circuit-breaker.

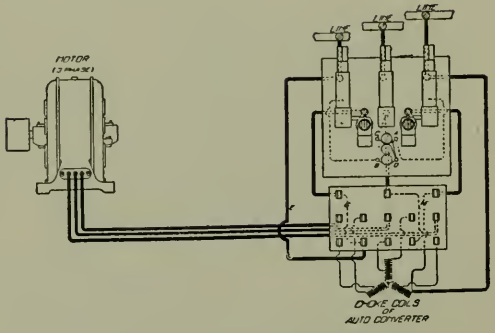


FIG. 372.—Connections of an overload and no-voltage circuit-breaker for protection of three-phase induction motors.

SECTION XVIII

RAILWAY CONTROLLERS AND EQUIPMENT

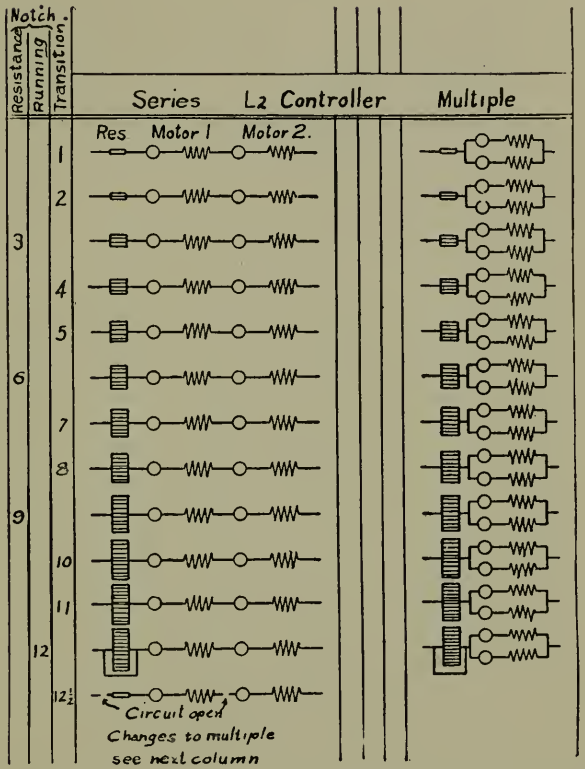


FIG. 373.—Connections of a two-motor equipment corresponding to the various controller notches when using a type L controller. This type of controller is used with the series-parallel system where the transition from series to parallel connections is made by open-circuiting both motors.

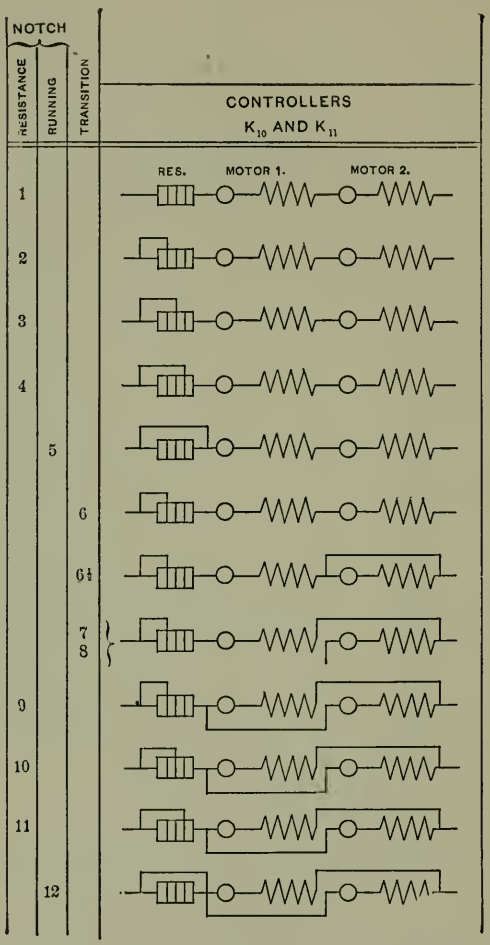


FIG. 374.—Connections of a two-motor equipment corresponding to the various controller notches when using a type K controller. This type of controller is used with the series-parallel system where the transition from series to parallel connection is made without open-circuiting the motors.

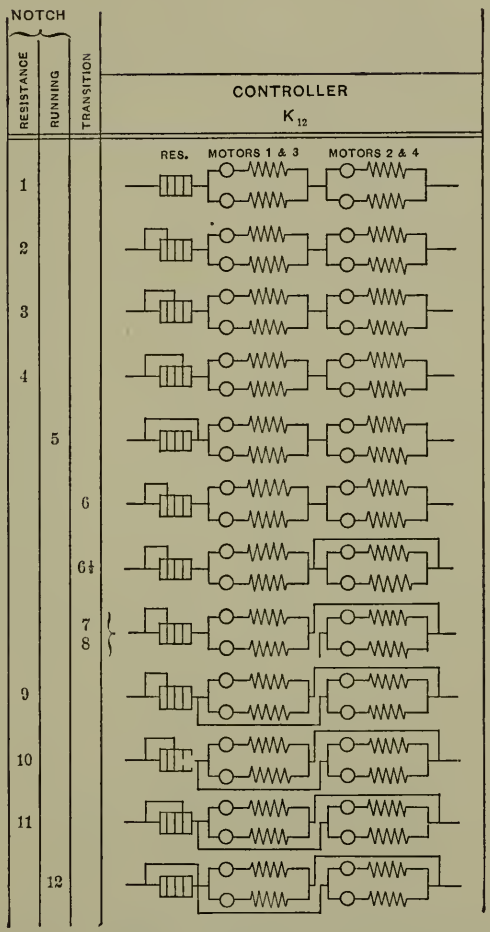


FIG. 375.—Connections of a four-motor equipment corresponding to the various controller notches when type K controller is used. For explanation of type K see Fig. 374.

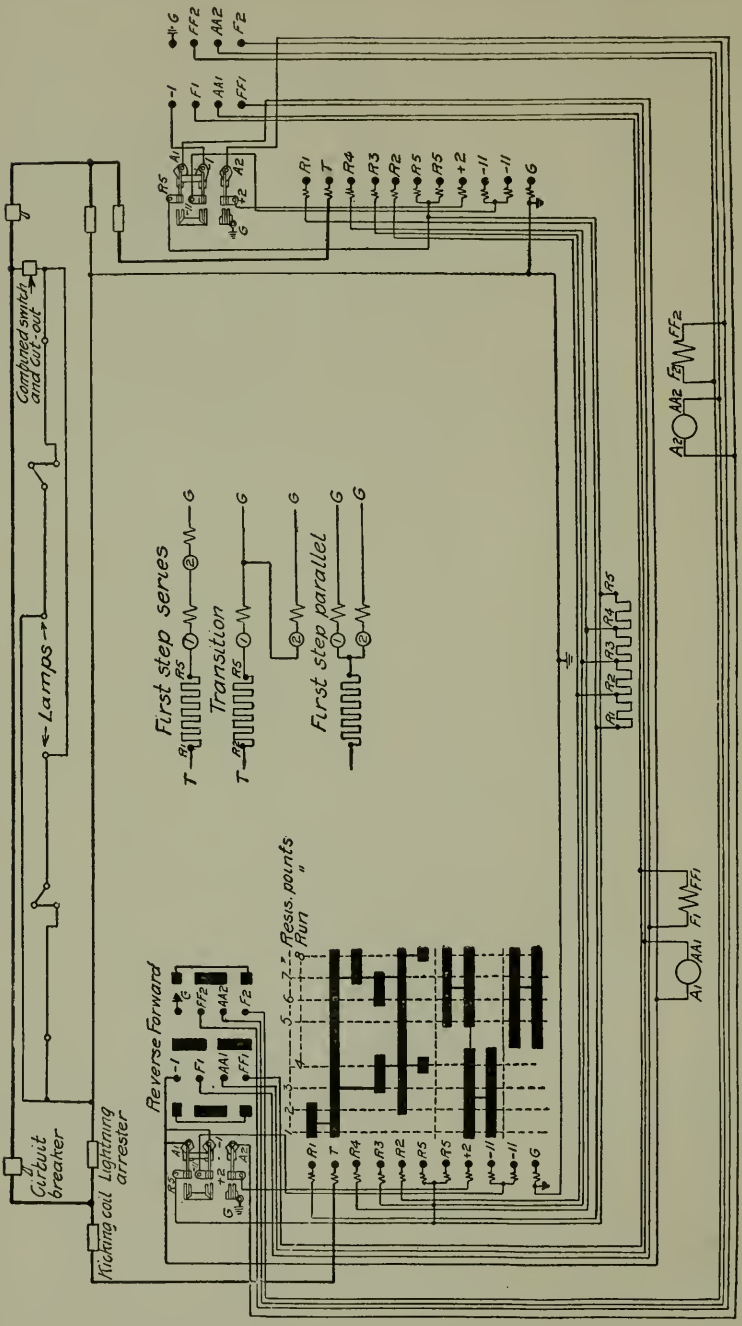


FIG. 376.—Wiring diagram of a K-36-A series-parallel controller for a two-motor equipment.

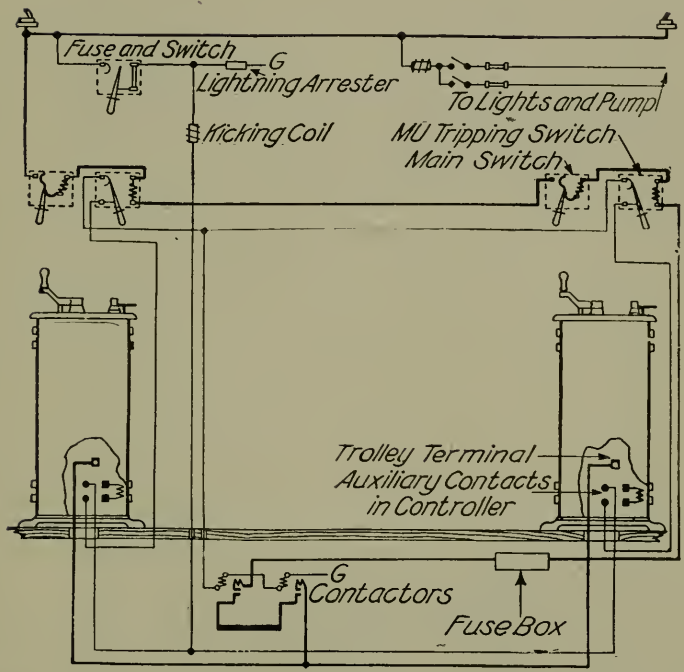


FIG. 377.—Wiring diagram showing method of connecting unit switches or contactors in a main circuit of an old equipment.

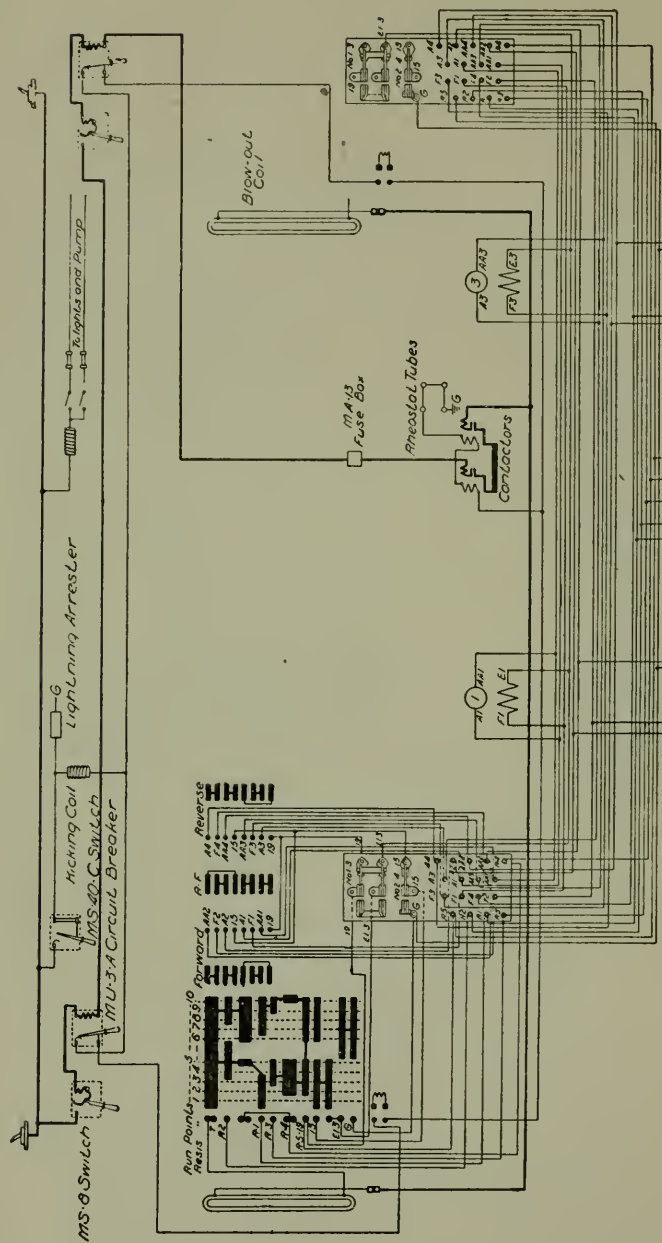


FIG. 378.—Wiring diagram of a K-28-F series-parallel controller using unit switches or contactors in the main circuit.

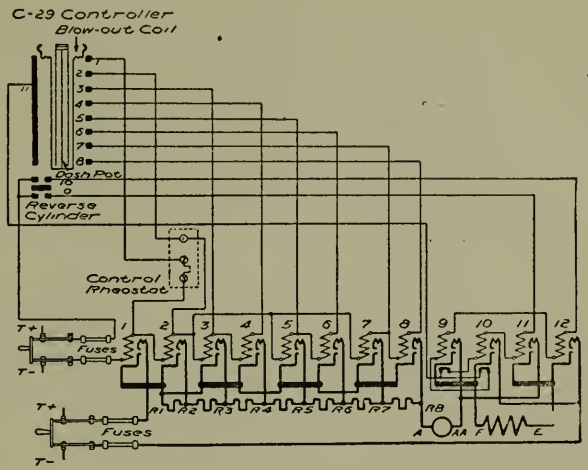
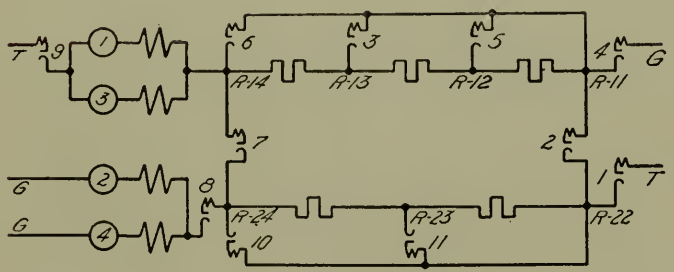


FIG. 397.—Connections of a Sprague-General Electric automatic controller for one motor.



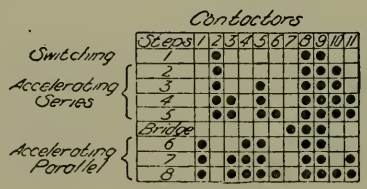


PLATE 1

MOTOR CIRCUITS, BRIDGE CONTROL

FIG. 380.—Motor circuits showing the method of bridging when passing from series to parallel connections with the Sprague multiple-unit control.

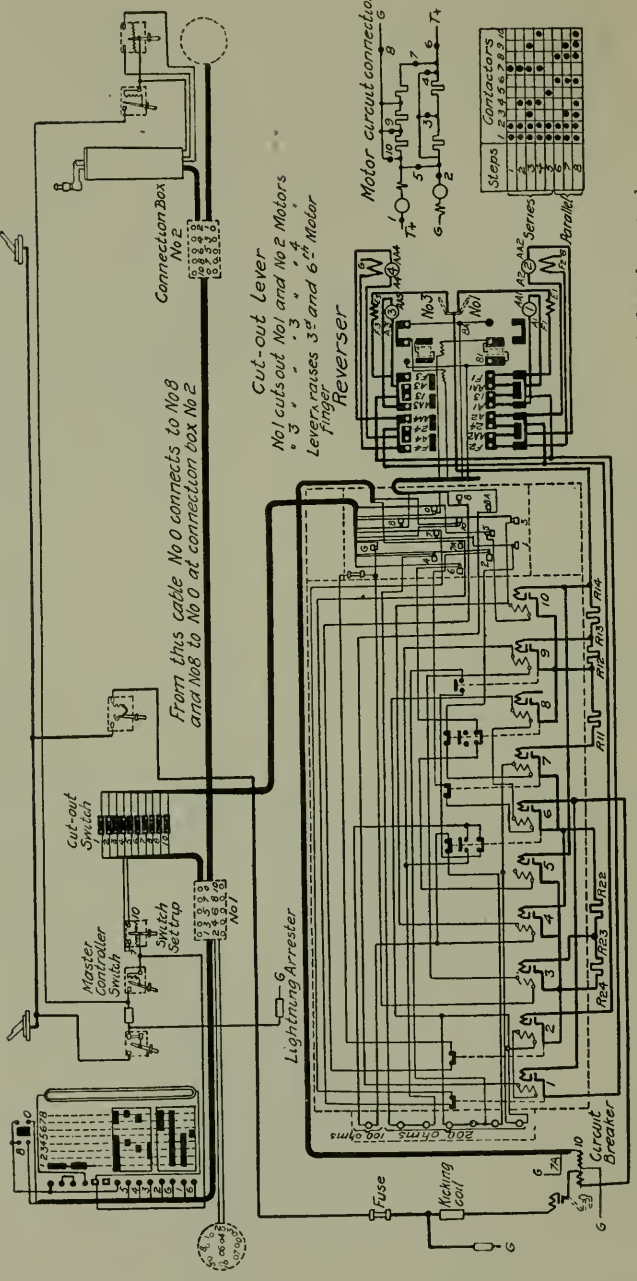


FIG. 381.—Wiring diagram of a Sprague-General Electric multiple-unit hand control.

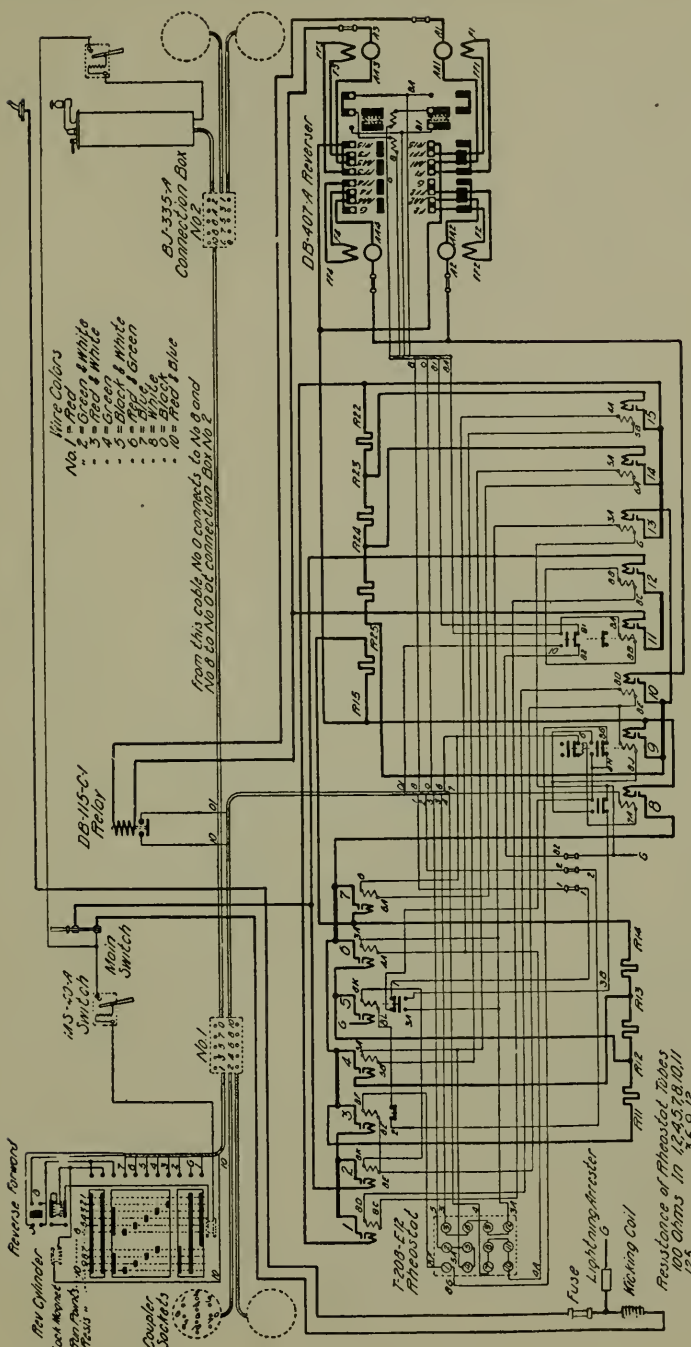


FIG. 382.—Wiring diagram of a four-motor equipment Sprague-General Electric multiple-unit control with automatic controller.

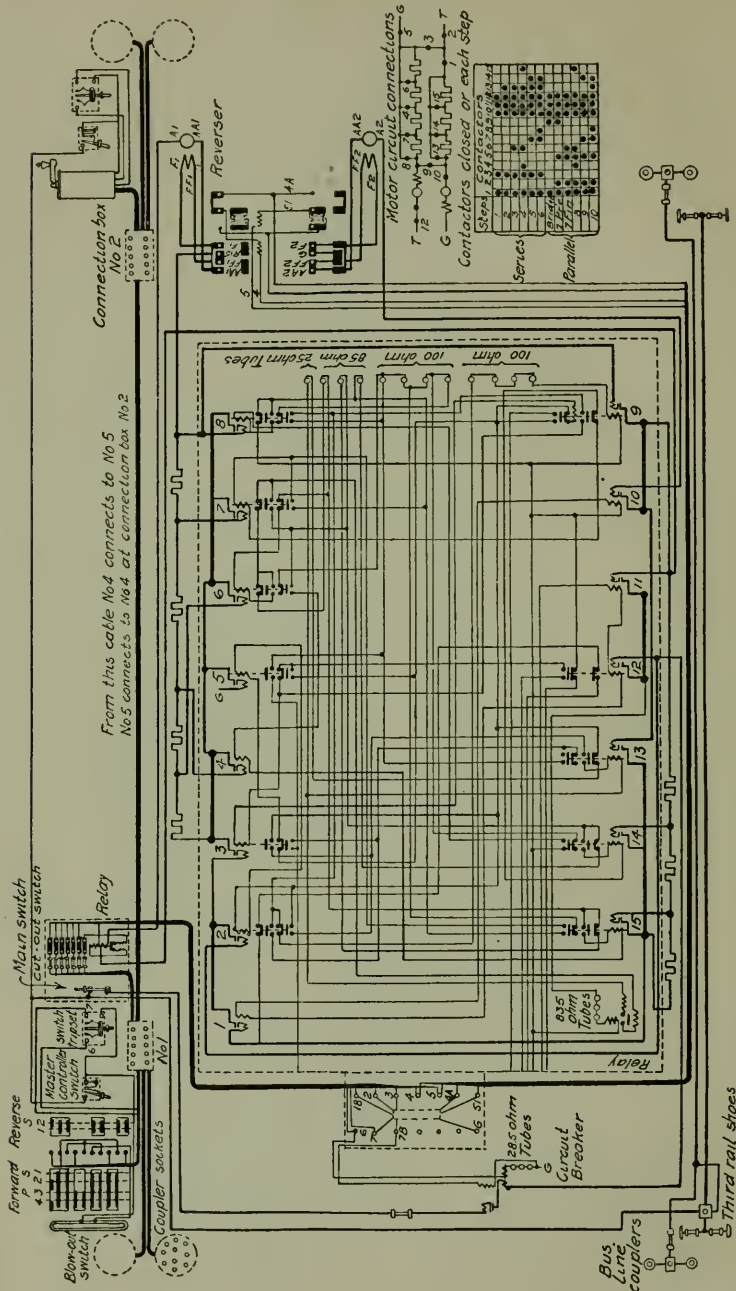
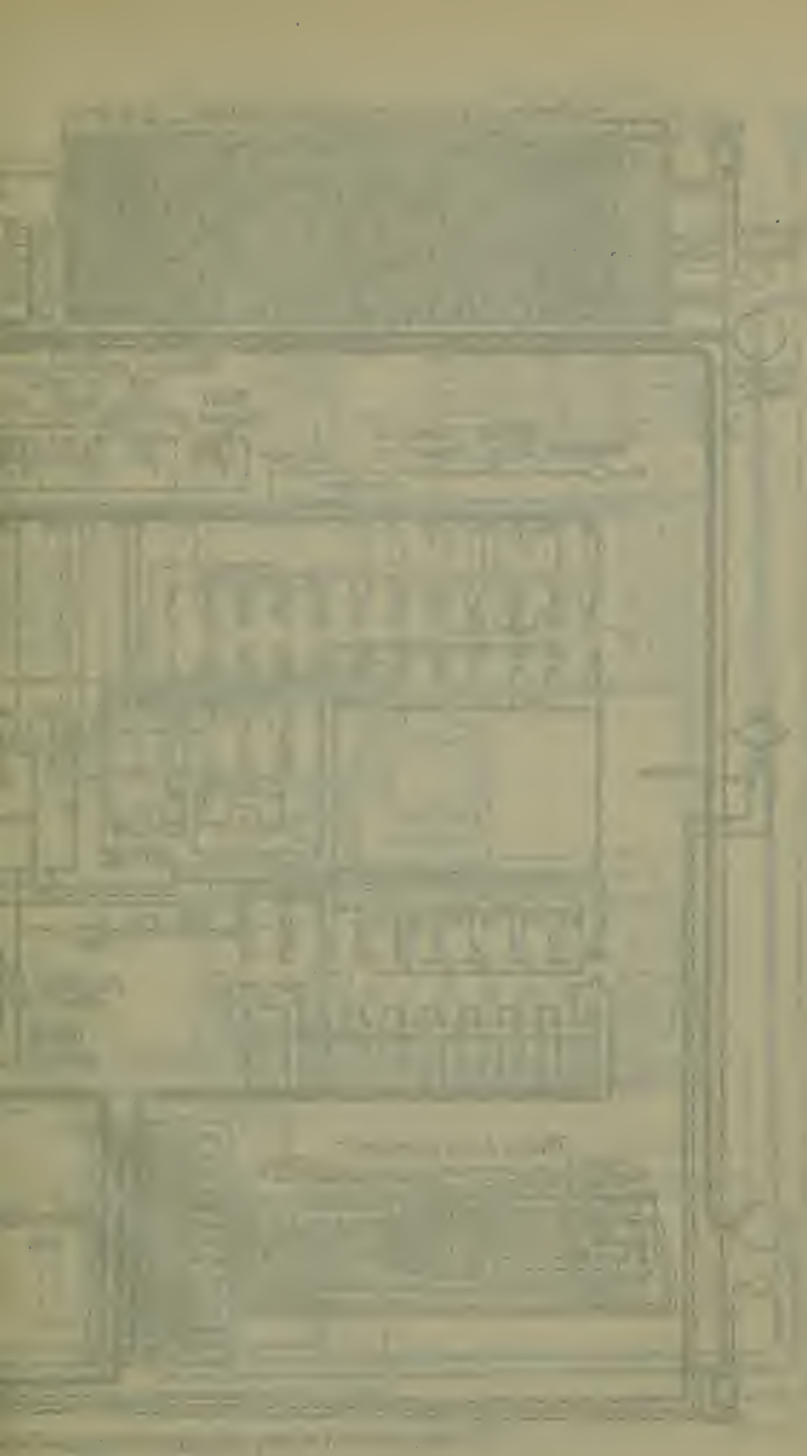


FIG. 384.—Wiring diagram of Sprague-General Electric automatic relay multiple-unit control.



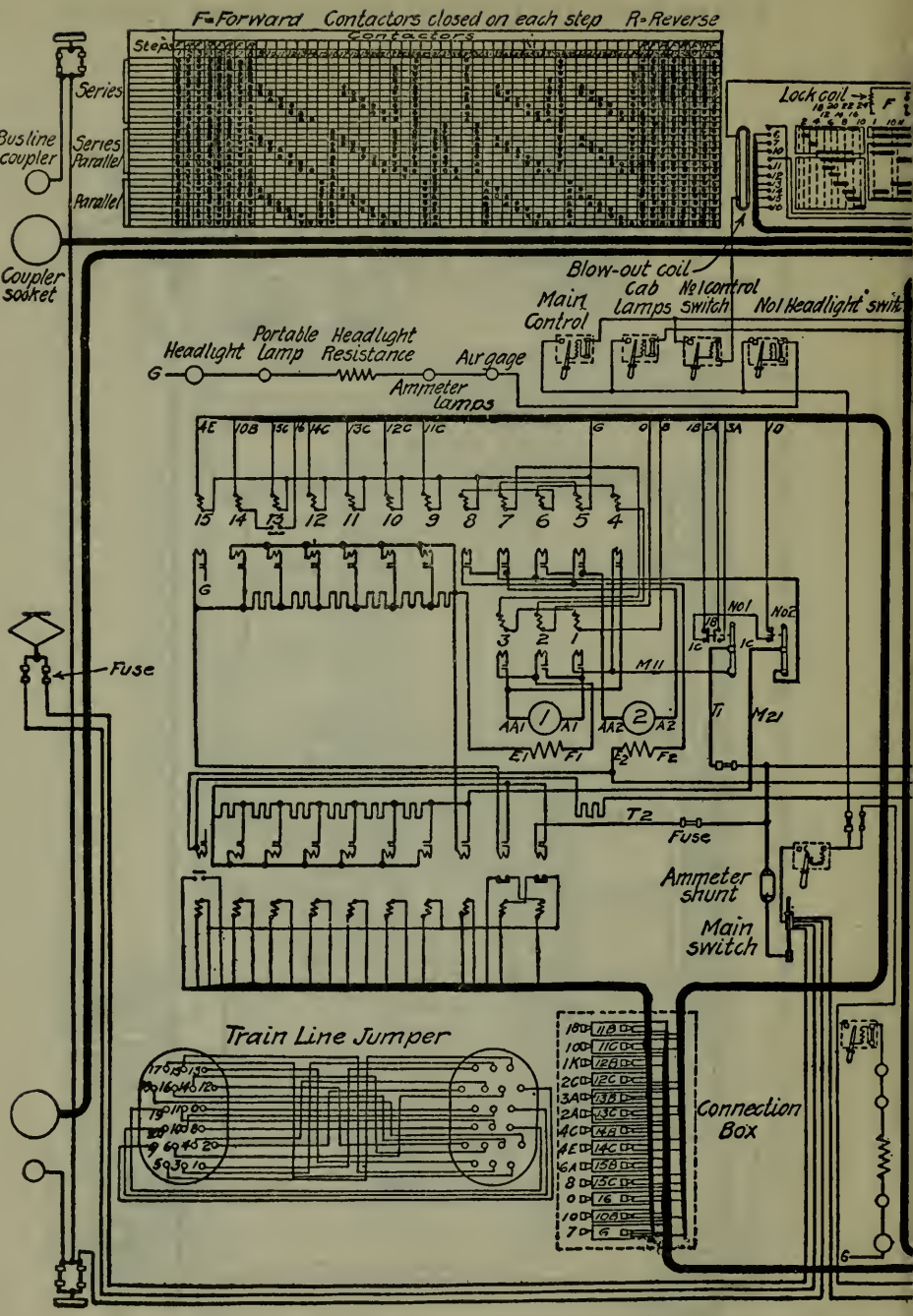
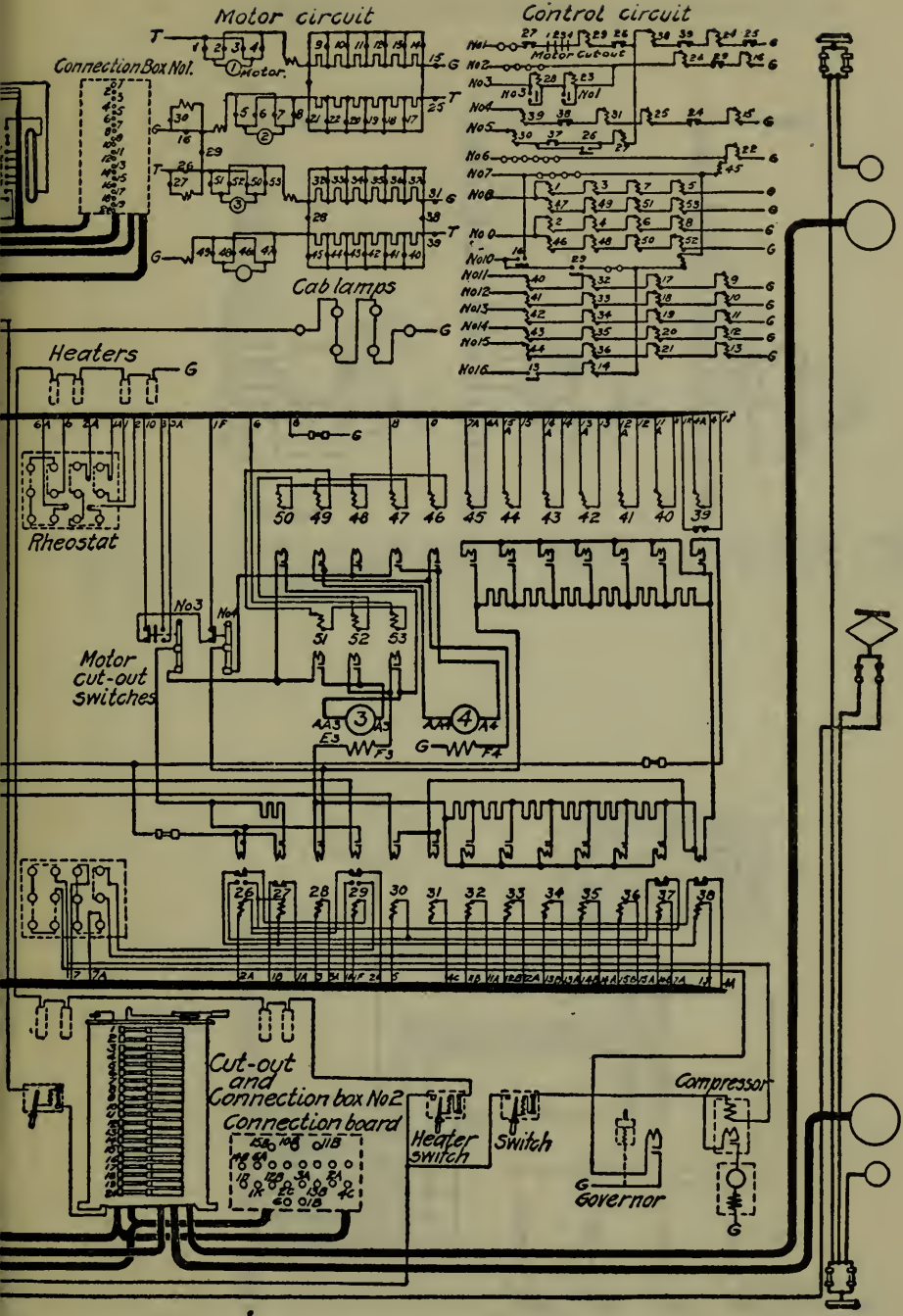
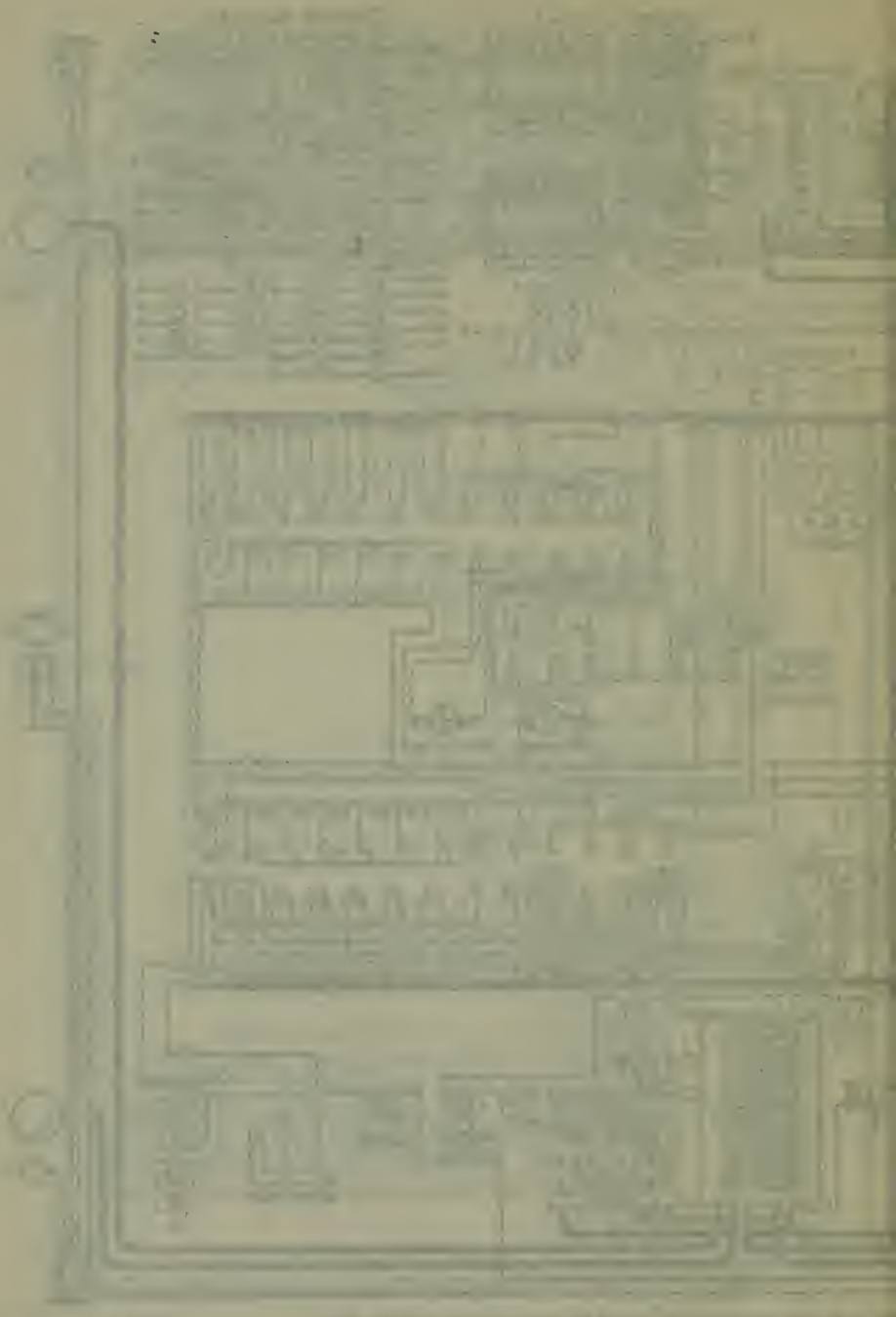


FIG. 383.—A wiring diagram of Sprague-General Electric r



ple-unit semi-automatic control for use on locomotives. (To face page 224.]



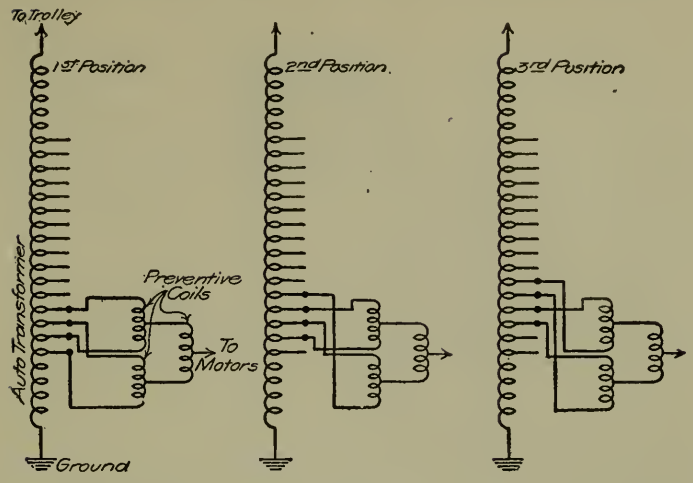


FIG. 385.—Diagram showing methods of operation of preventive coils. These prevent sparking and short-circuit currents when the voltage is varied by connecting to different taps for the auto transformer or compensator.

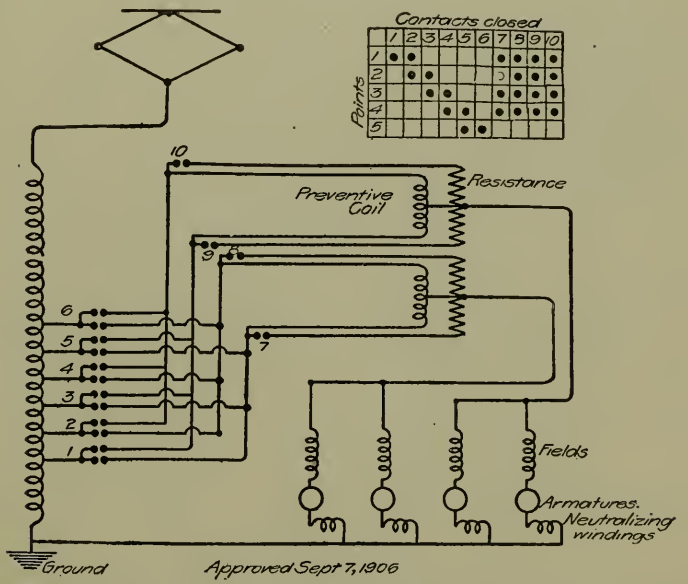


FIG. 386.—Diagram of connections for Westinghouse a.c. series motor tap control.

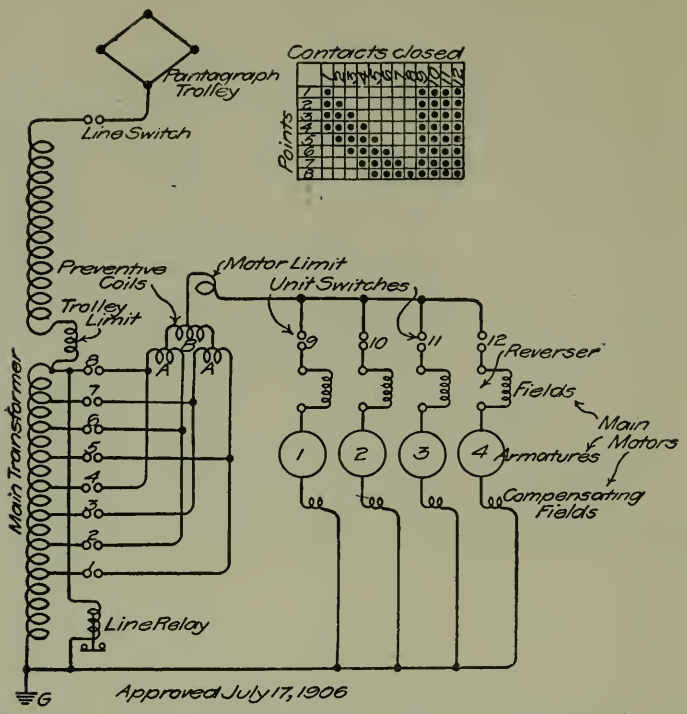


FIG. 387.—Connection diagram for Westinghouse multiple-unit control of a.c. series motors.

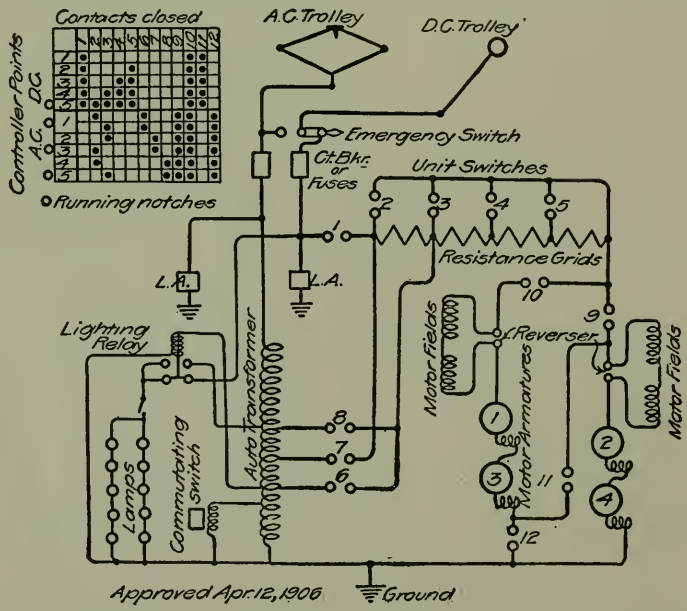


FIG. 388.—Connection diagram of four-motor equipment. A.c. series motors being used both on direct and alternating current.

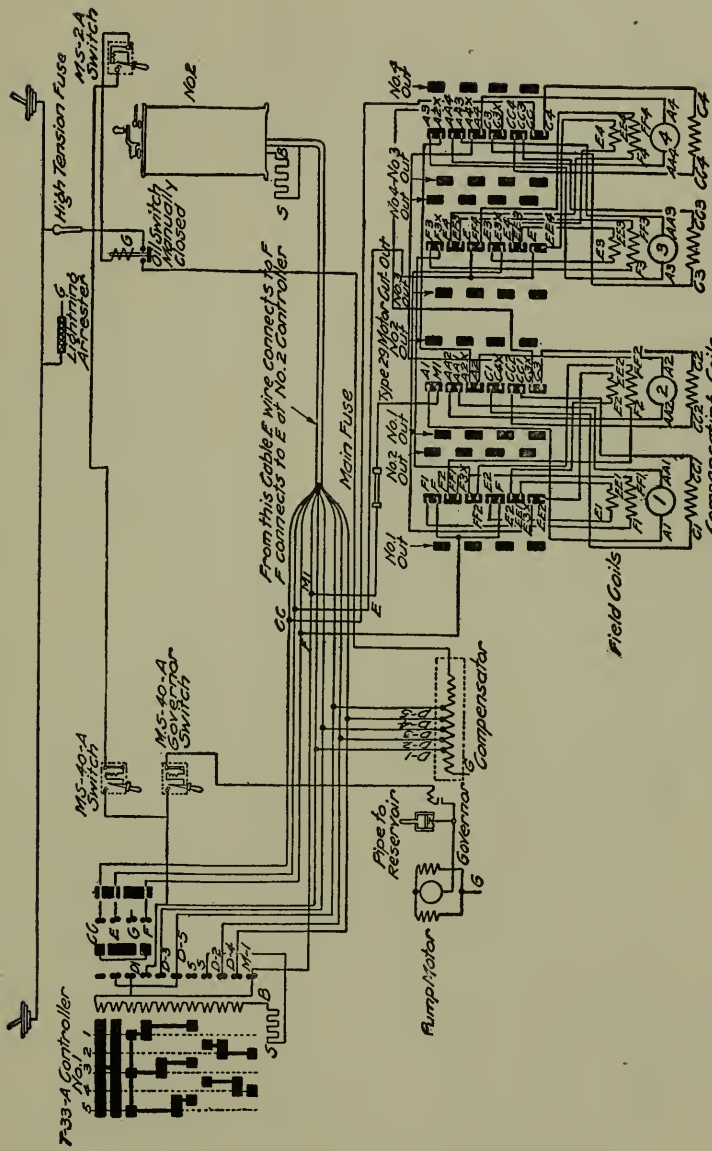


FIG. 389.—Wiring diagram of General Electric tap control system for a.c. series motor.

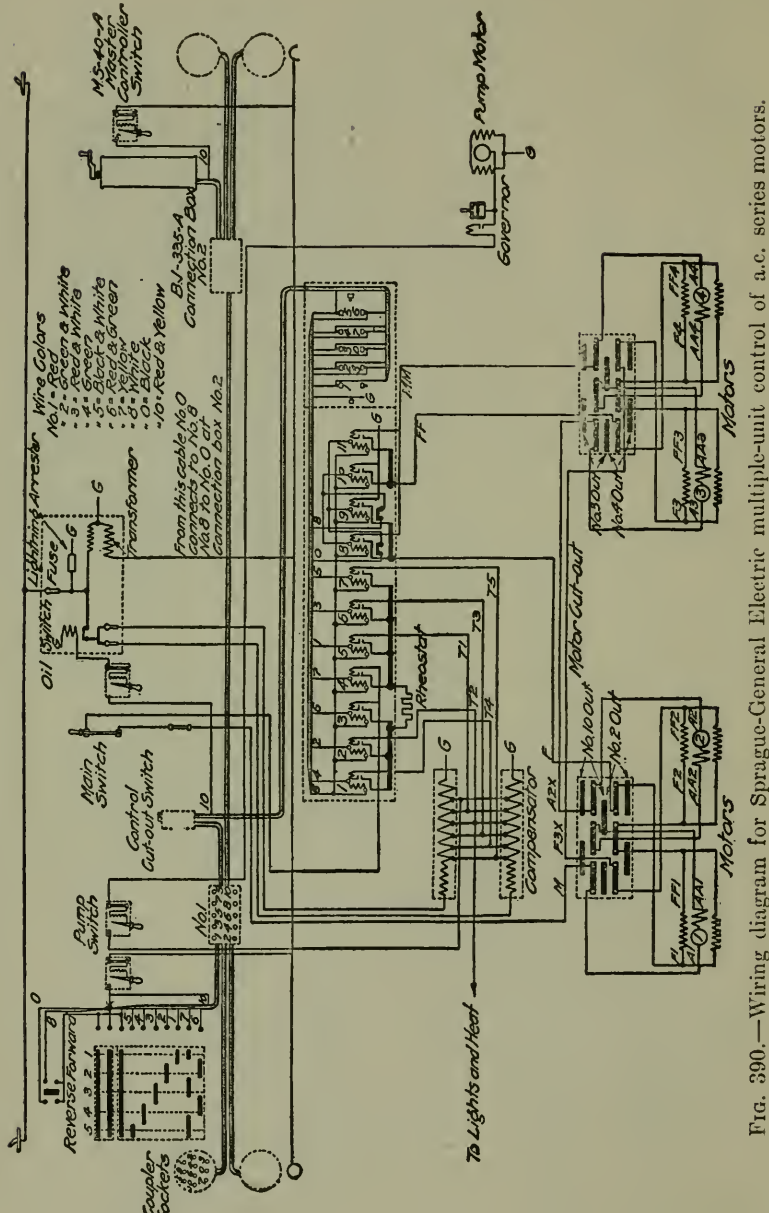


Fig. 390.—Wiring diagram for Sprague-General Electric multiple-unit control of a.c. series motors.

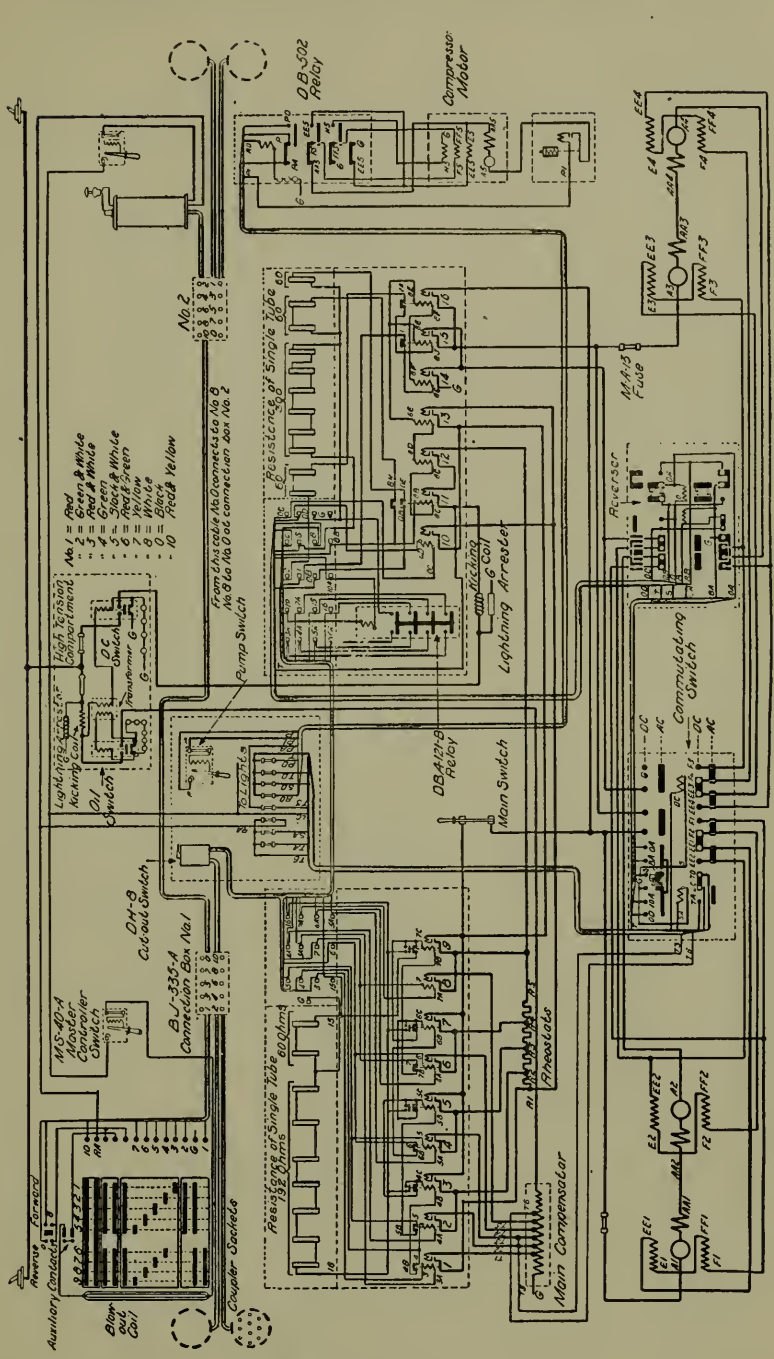


FIG. 391.—Wiring diagram of Sprague-General Electric multiple-unit control system for a.c. series motors. Control adapted to operate with either direct or alternating current.

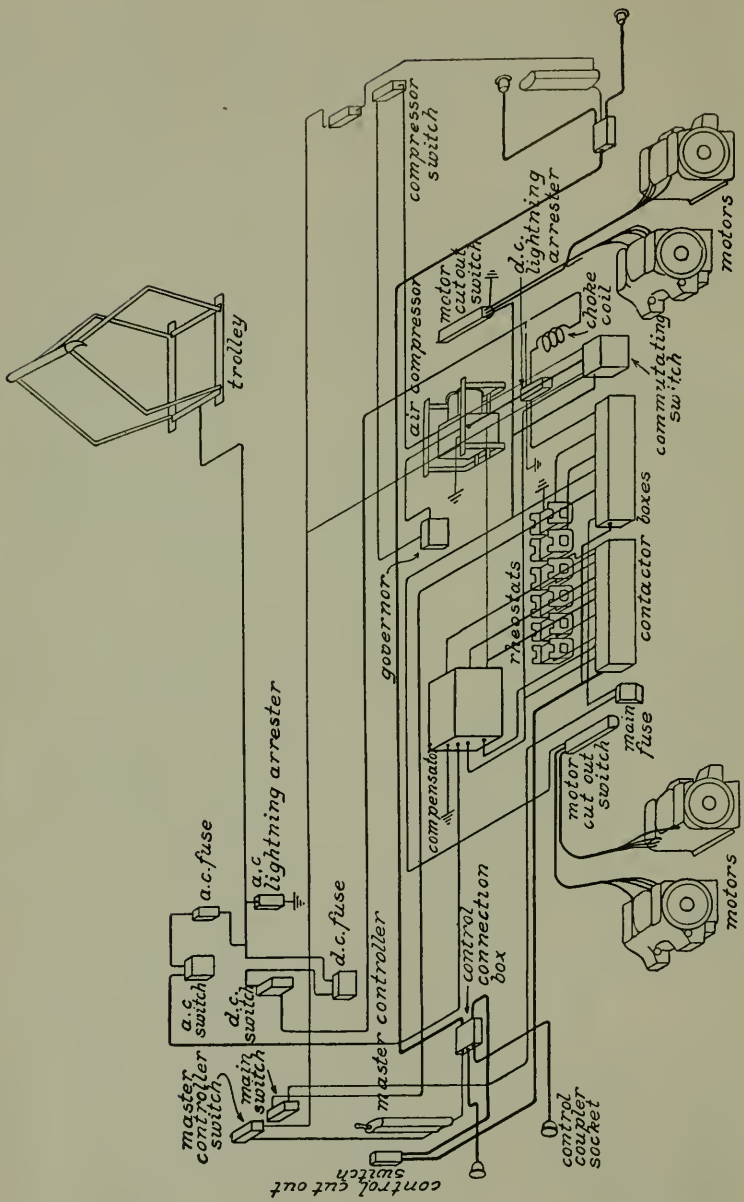


FIG. 392.—Connections and arrangement of the apparatus shown in wiring diagram Fig. 391.

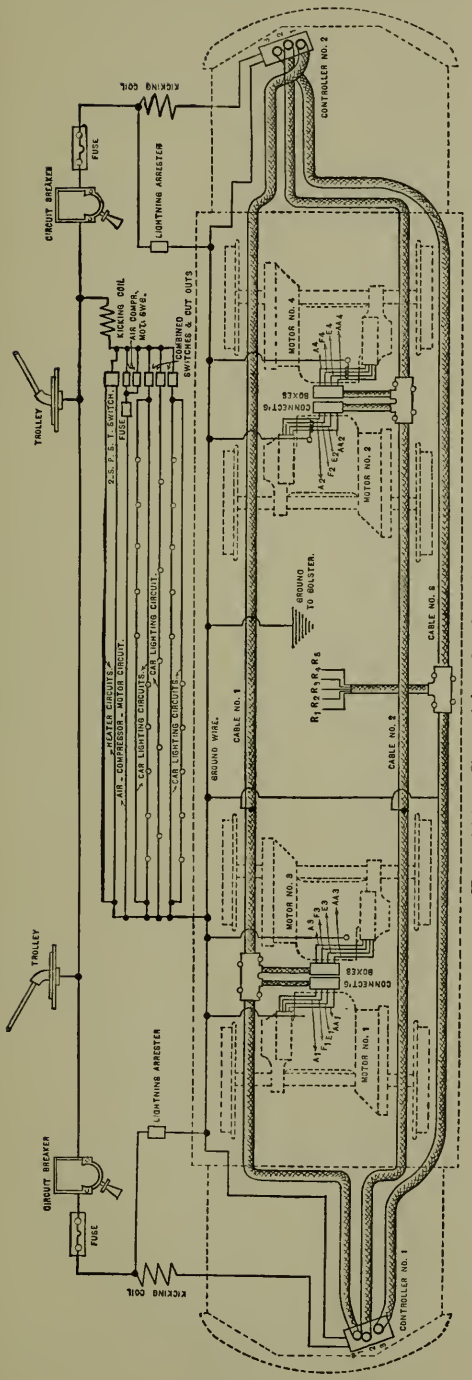


Fig. 393.—Car wiring for hand controller.

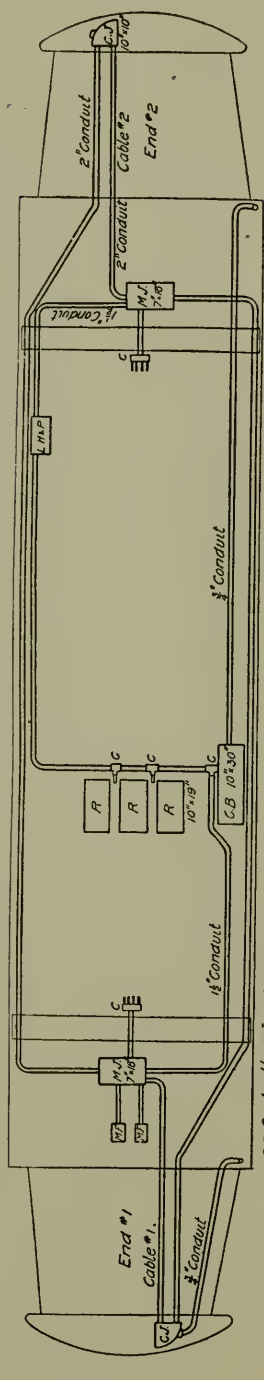


Fig. 394.—Car wiring for hand controller.

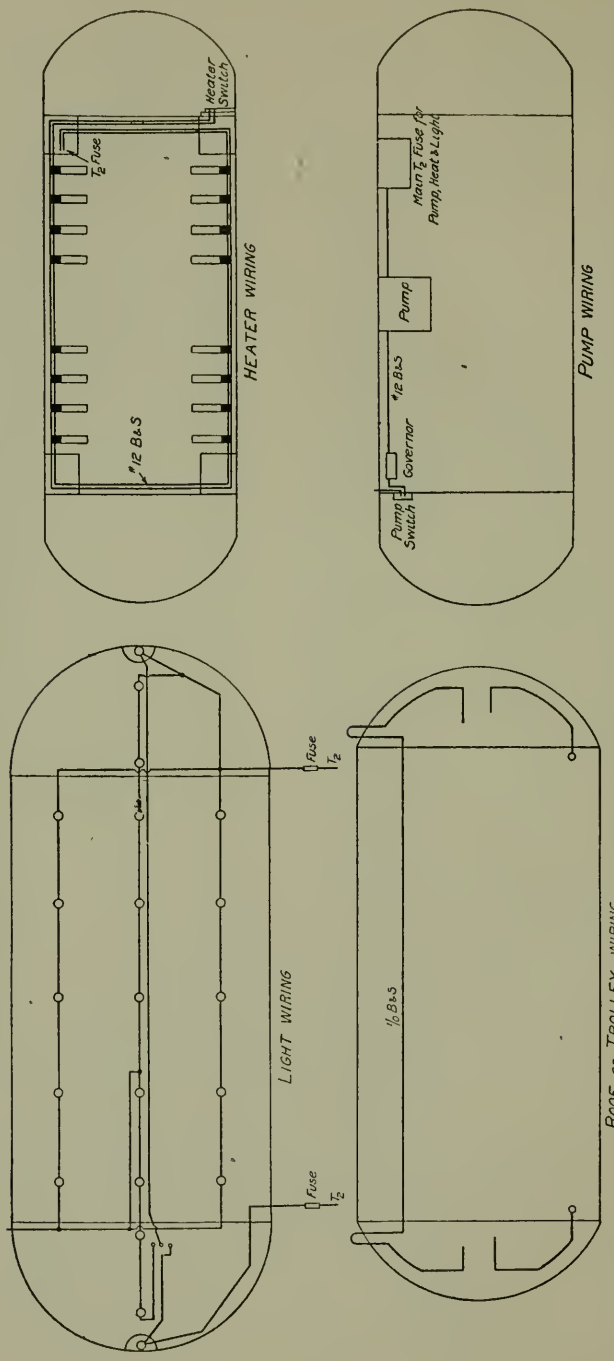


FIG. 395.—Wiring of auxiliary car circuits.

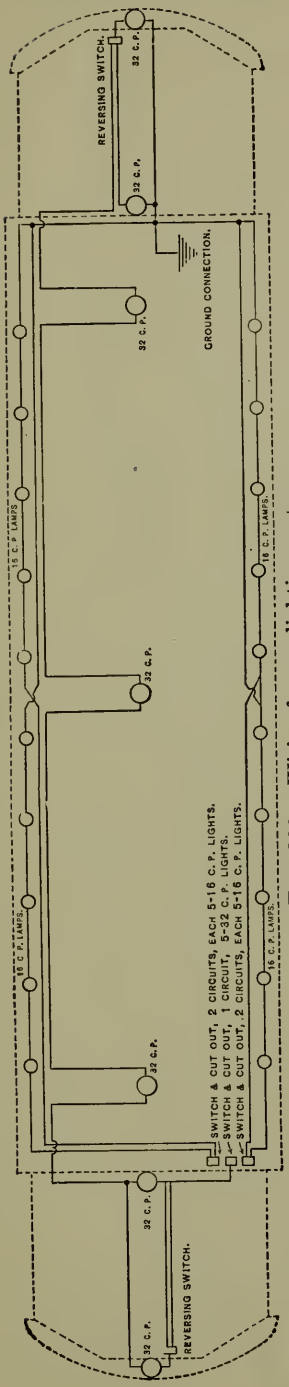


FIG. 396.—Wiring for car lighting system.

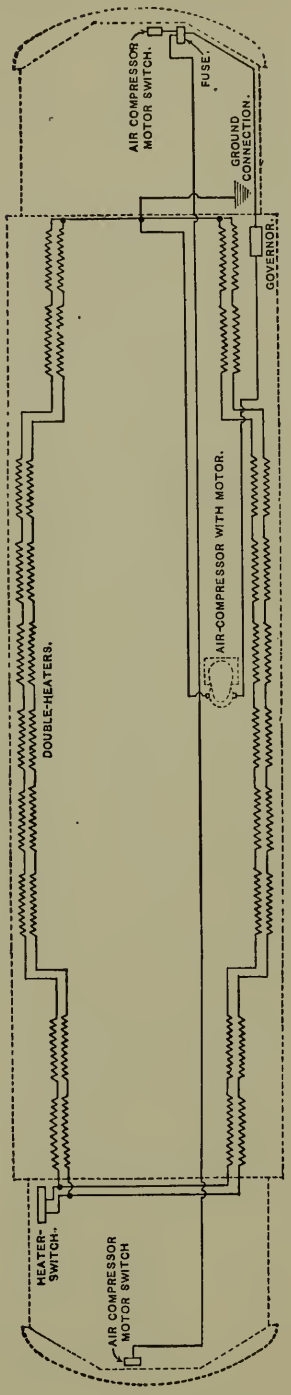


FIG. 397.—Wiring for car heating system.

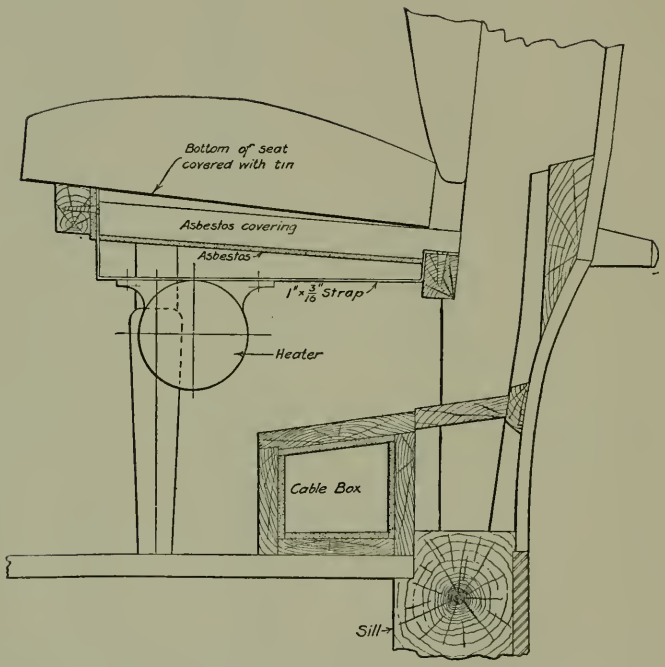


FIG. 398.—Location of heaters and cable box under longitudinal seats.

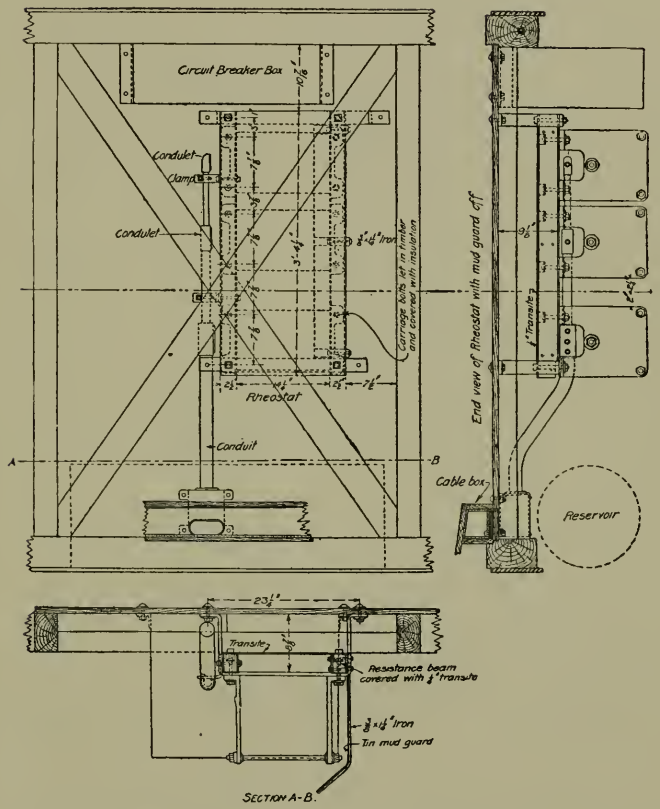


FIG. 399.—Method of installing rheostats under car floor.

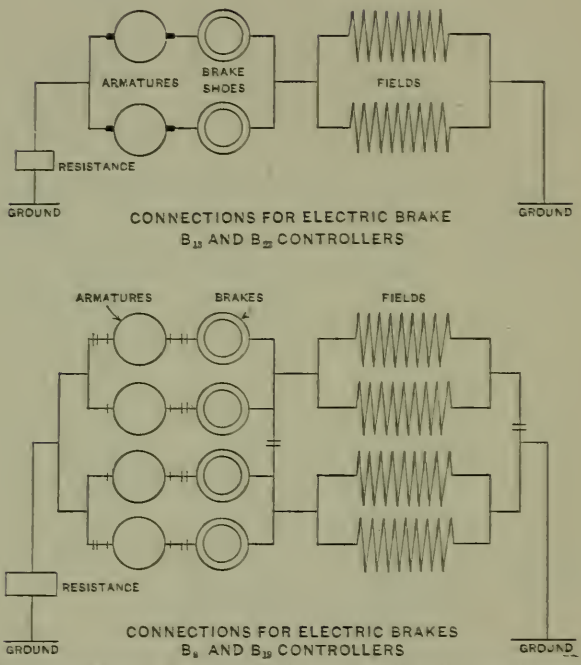


FIG. 400.—Connections for electric brakes used with type B controllers.

SECTION XIX

RAILWAY SIGNALS

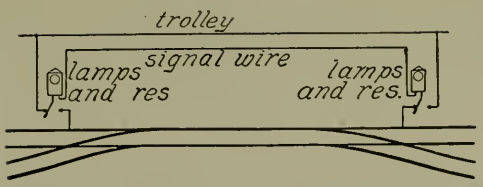


FIG. 401.—Connections for a manually operated block signal. When entering the block, the conductor throws the switch, lighting lamps at both ends of the block; and when leaving, he extinguishes them. The diagram shows the equipment for one block. Where two blocks meet there would, of course, be two lamps; one for each block.

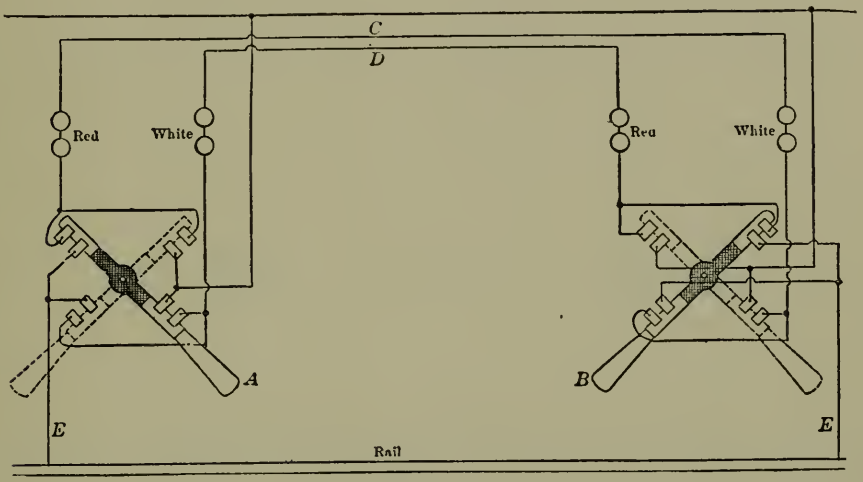


FIG. 402.

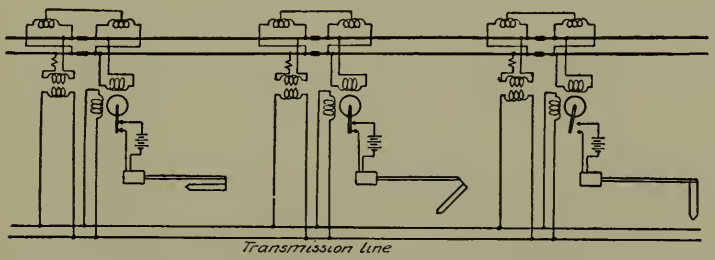


FIG. 403.—Signal system for double-track electric road. 25-cycle e.m.f. is impressed upon the transmission system which extends along the track. The track sections are connected to the line through transformers. In order not to interfere with the use of the track as return circuit for the direct current, the sections are insulated from each other and then connected together through inductive bonds. The signals are operated by two-phase relays, one phase being connected directly to the transmission line and one to the rails. The high inductance of the rail circuit produces sufficient phase displacement to establish a revolving field.

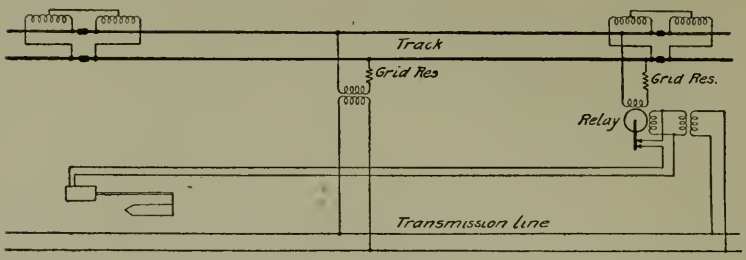


FIG. 404.—Signal system of the type shown in Fig. 403. Connections adapted to a long block system.

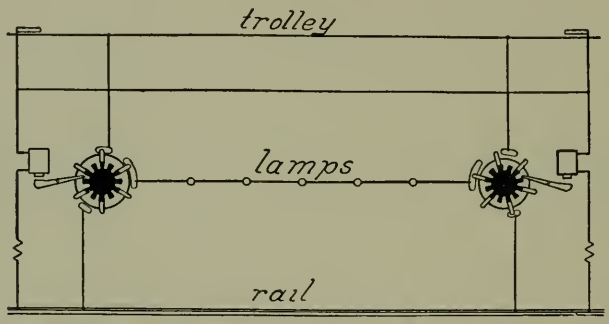


FIG. 405.—Automatic signal system for electric railroads. The relays are operated by energy from the trolley circuit, when the collector bridges, between the trolley wire and contact placed near it. Lamps are placed along the road, and the motorman can tell by them whether another car enters the block, or not, while he is there.

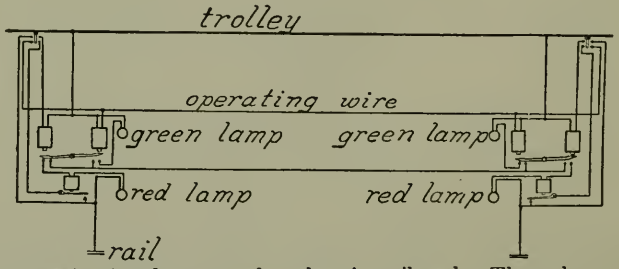


FIG. 406.—Automatic signal system for electric railroad. The relays are operated by energy from the trolley circuit through pendant switches operated by the trolley wheel. The red light indicates a car approaching, and the green light indicates a car going in the same direction, and no light indicates clear block.

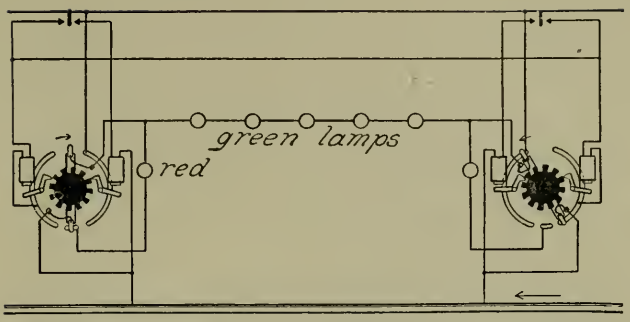


FIG. 407.—Car-counting signal system. A trolley operated switch excites a relay which pulls the switch around one notch. When entering, the car causes the switch to move one notch in one direction, and in leaving, it moves the switch one notch in the opposite direction so hat the signals indicate the number of cars in the block at any instant.

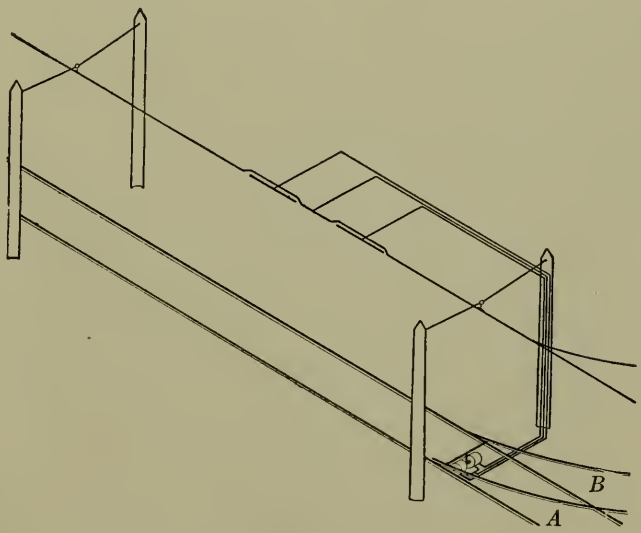


FIG. 408.—Connections for an electrically operated track switch. The magnets are energized by inserting them between the trolley wire and the trolley wheel. By passing the insulated section of the trolley with the power on or off, the track magnet can be energized or left dead, respectively.

SECTION XX

MISCELLANEOUS INTERIOR WIRING

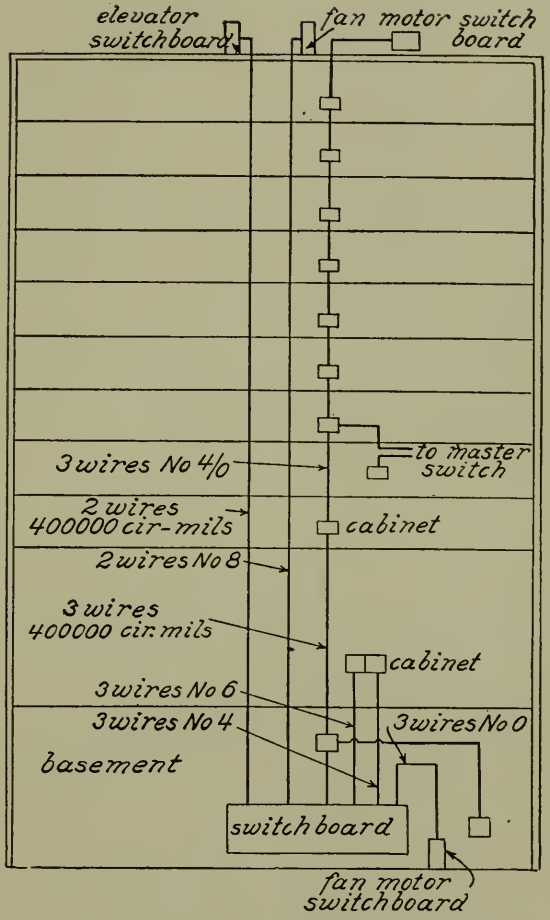


FIG. 409.—Feeder system for an office building.

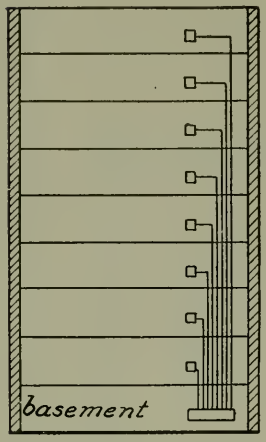


FIG. 410.—System of individual feeders for an office building.

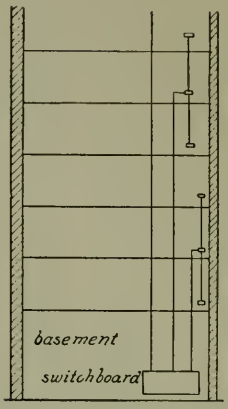


FIG. 411.—Feeder system combining methods shown in Figs. 409 and 410.

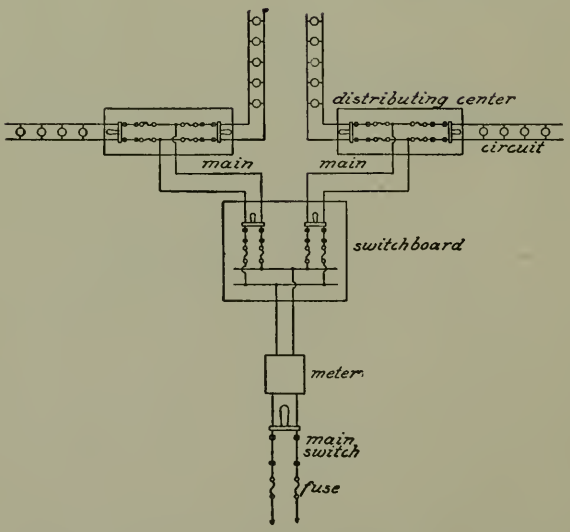


FIG. 412.—Service distribution from two-wire circuit.

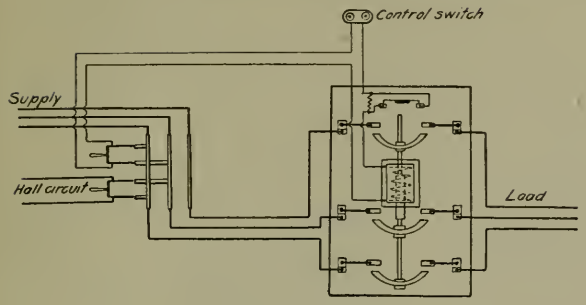


FIG. 413.

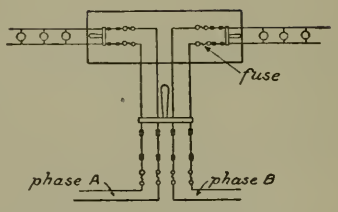


FIG. 414.

FIG. 413.—Method of distribution from three-wire circuit with automatic solenoid main switch controlled from a distance by a push switch.

FIG. 414.—Service distribution from two-phase circuit for lighting.

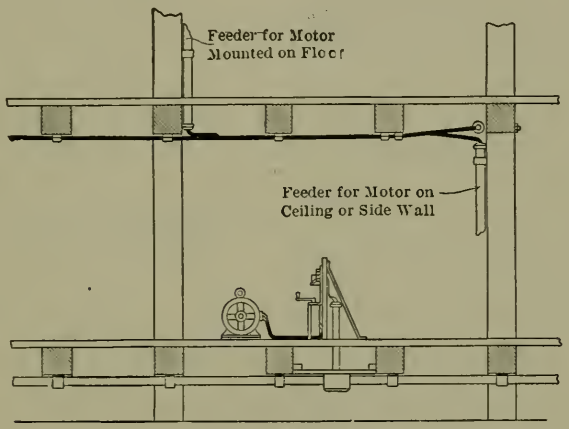


FIG. 415.—Motor wiring.

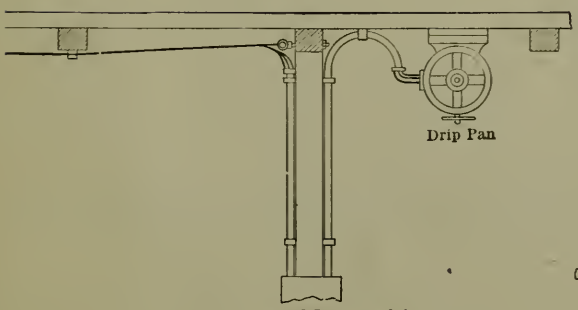


FIG. 416.—Motor wiring.

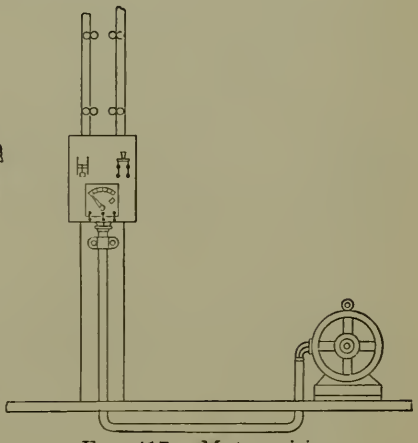


FIG. 417.—Motor wiring.

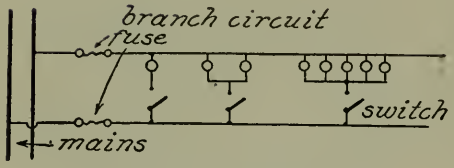


FIG. 418.—Various methods of lamp control.

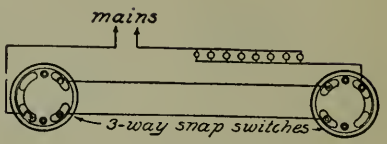


FIG. 419.—Lamp circuit control from two points.

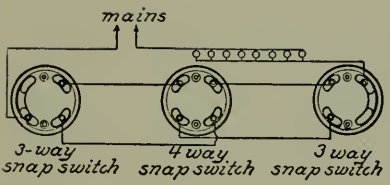


FIG. 420.

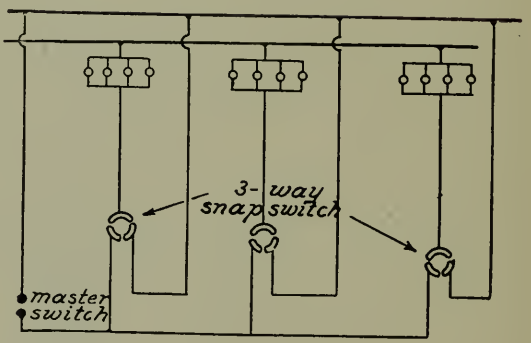


FIG. 421.

FIG. 420.—Lamps controlled from three or more points.

FIG. 421.—Several groups of lamps controlled in individual groups and as a whole. This type of circuit is known as the burglar circuit, being possible to light and extinguish all lamps in the house with one switch, providing the group switches stand in the off position.

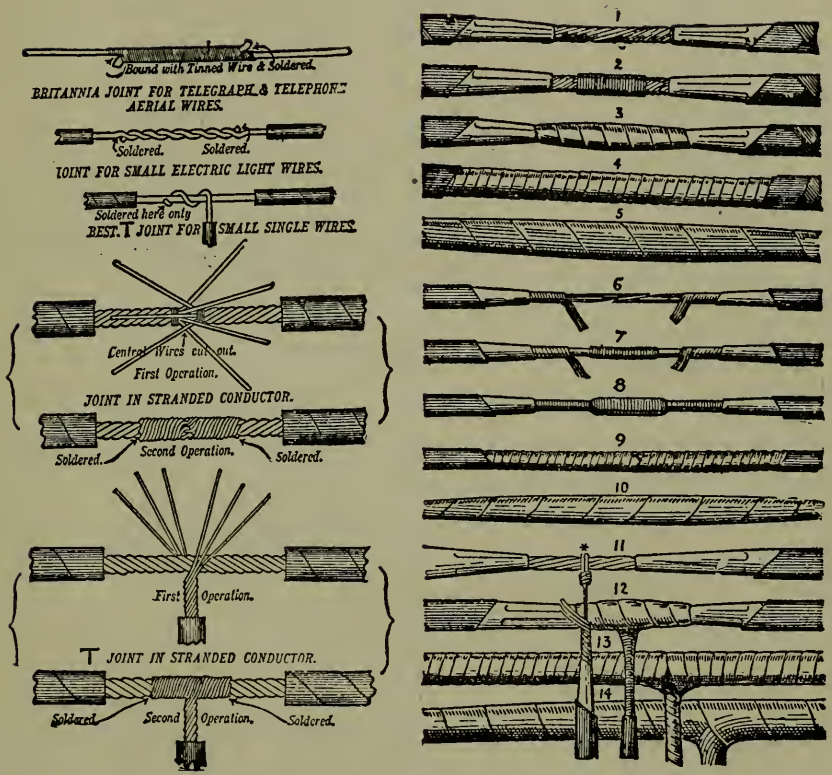


FIG. 422.—Standard methods of joining electrical conductors.

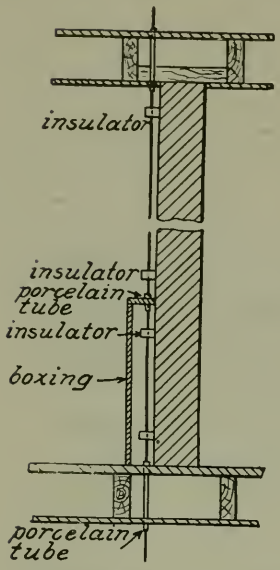


FIG. 423.—Method of running wiring on side walls.

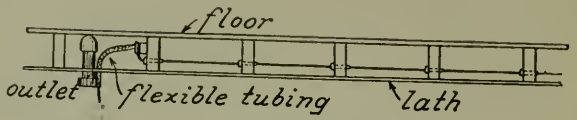


FIG. 424.—Concealed knob and tube work.

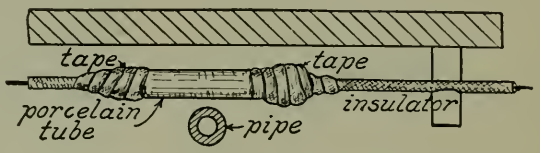


FIG. 425.—Wire passing over pipe.

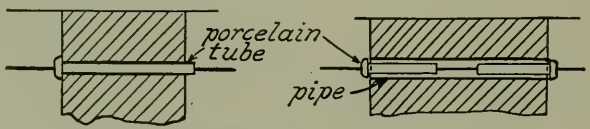


FIG. 426.—Wire passing through walls.

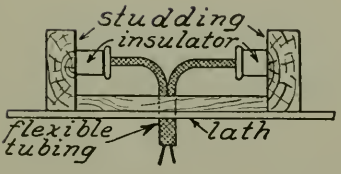


FIG. 427.—Concealed wiring at an outlet.

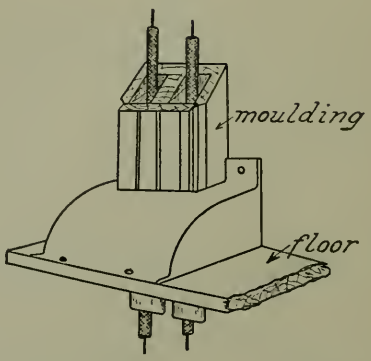


FIG. 428.—Kicking box for moulding work.

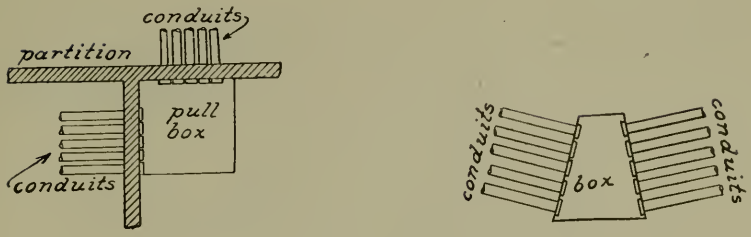


FIG. 429.—Applications of pull boxes.

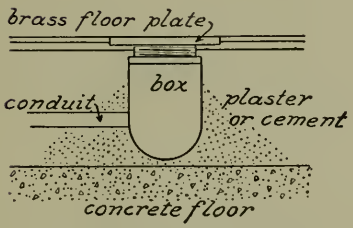


FIG. 430.—Floor outlet.

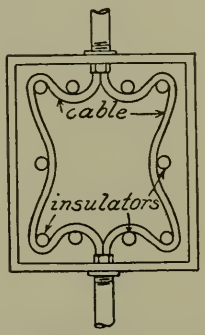


FIG. 431.—Method of supporting cables in long vertical runs.

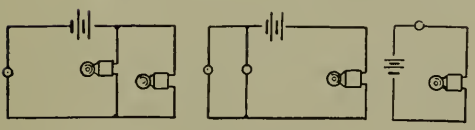


FIG. 432.—Bell wiring for single push, single bell with two pushes, and two bells with one push.

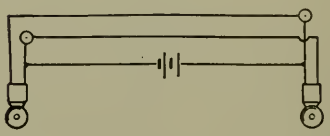


FIG. 433.—Return-call bell wiring system.

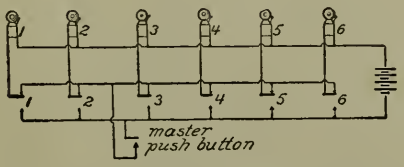


FIG. 434.—Bells operated with a double push (see Fig. 432). Bells can be rung individually or together with a master push button.

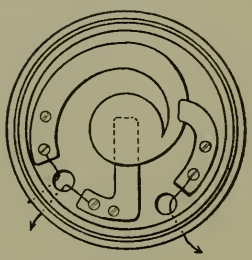


FIG. 435.—Double-contact push button.

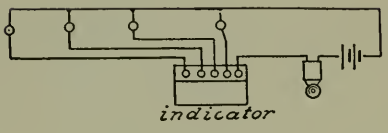


Fig. 436.

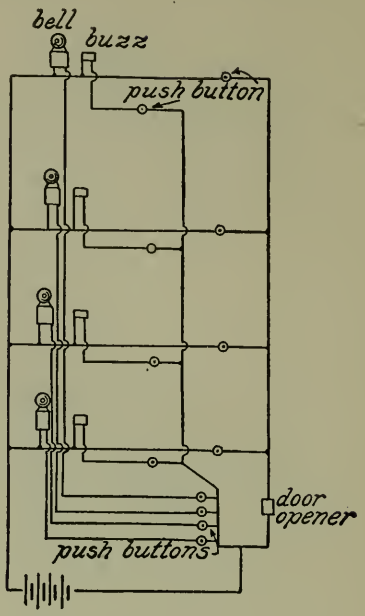


Fig. 437.

Fig. 436.—Wiring for bell and indicator with several pushes.

Fig. 437.—Bell wiring for apartment houses. Bells are rung from hall downstairs; door opener operated by pushes in the apartments, and buzzer rung by pushes at the apartment doors.

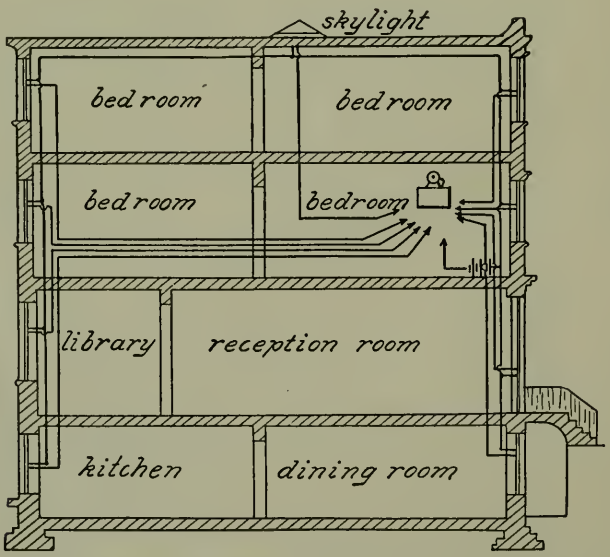


Fig. 438.—Open-circuit burglar alarm system. If the circuit is closed at any point, the burglar alarm is operated.

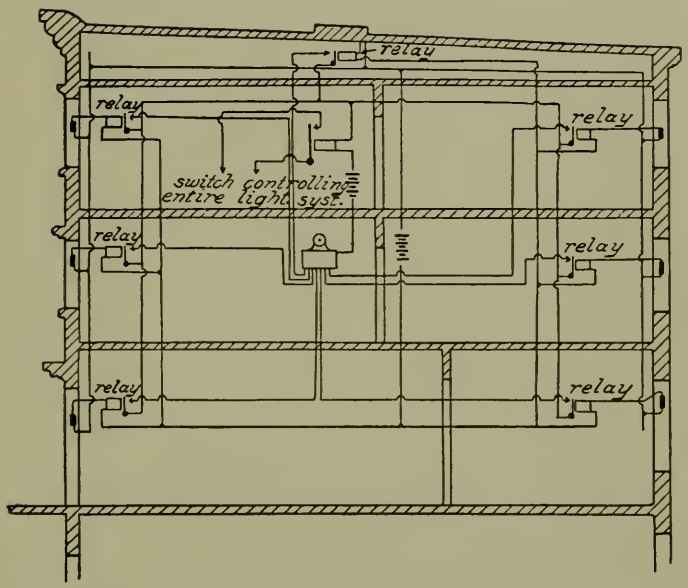


FIG. 439.—Closed-circuit burglar alarm system. If the circuit is open at any point, the relays close switches in the main circuit and operate the alarm bell.

See Standard Handbook, Section 18, for further diagrams.

D. C. Lovelace,
F. G. S. Co.,
Susanville,
California.